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Plate I.

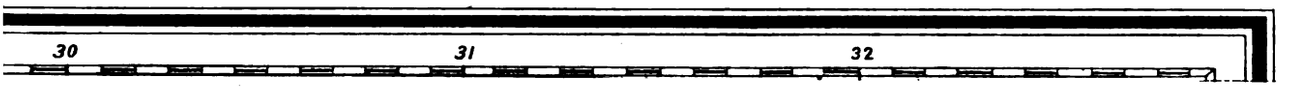

Plate I.

South Africa. Geological Survey.

E. R.

TRANSVAAL

MINES DEPARTMENT.

REPORT

OF THE

GEOLOGICAL SURVEY

For the Year 1907.

PRICE 7s. 6d.

PRETORIA:

PRINTED AT THE GOVERNMENT PRINTING AND STATIONERY OFFICE.

1908.

1662—9/4/08—1,000.

Attention may, however, be drawn to the following economic work which has been done by the Survey since its inception :—

(1) Detailed surveys of the Witbank, Middelburg, and Komatipoort Coal-fields.

(2) Detailed survey of the Lydenburg and Pilgrims Rest Gold-fields and of the Kaapsche Hoop area.

(3) Report on the Haenertsburg and Leydsdorp Gold-fields.

(4) Report on the magnesite of Malelane.

(5) Report on the Seta and Messina mines.

(6) Examination of the auriferous conglomerates of the Witwatersrand beds in the Venterskroon area, and of the alluvial and other gold occurrences west of Krugersdorp (1907).

(7) Investigation of the chromite deposits of the Lydenburg and Rustenburg Districts.

(8) Examination of the tin-producing areas of the Waterberg District, now being carried on.

(9) Examination of the Malmani Gold-field and lead and zinc deposits of the Marico District, now being carried on.

In addition to the four special memoirs which have already been issued, it is intended where possible to continue from time to time the publication of special memoirs dealing with special subjects, such as those mentioned above, commencing with a memoir on the cassiterite deposits now being investigated, and to continue with other reports on base metals deposits and their relation to the geological formations.

The work which has already been completed, as shown on the key plan, has achieved certain valuable geological results, among which may be mentioned :—

(1) The chief geological systems (or larger groups of formations) with their more important subdivisions have now been arranged and classified on a sound basis, and their structural features in the central part of the Colony established.

(2) Considerable progress has also been made in the correlation of Transvaal formations with those of the neighbouring Colonies.

(3) The geological position of various formations whose relations were formerly obscure have now been settled.

(4) The stratigraphy of the Karroo and Waterberg Systems in the Transvaal has now been very clearly defined.

(5) The detailed mapping of the Black Reef, Dolomite and Pretoria Series, which form essentially the key to the structure of the Central Transvaal, has now been completed from Pretoria, where the commencement of the survey work was made ; westward almost to Zeerust ; eastward through the Barberton and Lydenburg Districts ; and northward to Haenertsburg, and almost to the neighbourhood of Potgietersrust.

(6) A considerable increase has been made to our knowledge of the Transvaal coal-measures on the High Veld, and of the former glaciation of the country.

(7) Detailed investigation has been made into the extensive granite masses, and of the other igneous rocks of the Central Transvaal, and their relations to the sedimentary formations, all having an important bearing on the occurrence of the base metal deposits now being opened up in the north.

(8) Considerable additions have been made to our knowledge in regard to conditions obtaining in various parts of the country connected with underground waters, especially in the areas occupied by the Dolomite.

With regard to the sheet maps being issued by the Survey, these will inevitably always be somewhat behind the work described in the Annual Reports. The next sheets to be published will be (4) Rustenburg, (5) Potchefstroom, (6) Belfast, (7) Lydenburg, (8) Zeerust. Each sheet will be accompanied by a description dealing with the salient features of the locality, with special reference to its economic geology.

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The total area mapped by the Survey is shown in the following table :—

Year.	Area in square miles.	Cost of Survey for the year.	District.
1904	3,167	£5,502	Pretoria and Waterberg, Middelburg and Waterberg, Pretoria.
1905	3,778	6,671	Barberton, Waterberg, Pretoria and Middelburg, Lydenburg, Pretoria and Rustenburg.
1906*	4,963	6,544	Pretoria and Witwatersrand, Middelburg, Lydenburg, Carolina, Pretoria and Rustenburg.
1907	4,915	6,541	Potchefstroom, Lydenburg, Zoutpansberg, Rustenburg and Witwatersrand, Waterberg and Rustenburg.
Total Sq. Miles	16,823		

While the total area mapped during 1907 was as shown above, 4,794 miles of boundary lines were completed, as compared with 4,798 completed during the previous twelve months.

The staff for the year reported on consisted of the following officers:—

Director	H. Kynaston.
Geologists	E. T. Mellor. A. L. Hall. W. A. Humphrey.
Curator and Librarian	S. M. Tweddill.
Chief Clerk	P. M. O'Connor.
Draughtsman	F. A. Steart.
Curator's Assistant	C. C. Gardthausen.

The main heads of the cost of the work for the twelve months ended December, 1907, were as follows :—

Salaries and Allowances	£5,016 6 4
Transport and Subsistence	994 1 10
Public Works Department (heavy transport) ..	434 7 6
Museum and Laboratory, and Miscellaneous Expenses..	96 9 0
	£6,541 4 8

I have the honour to be,

Sir,

Your obedient servant,

H. WARINGTON SMYTH,
Secretary for Mines.

To the Honourable
The Minister of Mines, Pretoria.

* An additional geologist, Dr. Humphrey, was appointed during this year.

MINES DEPARTMENT,
GEOLOGICAL SURVEY OFFICE,
Pretoria, 28th July, 1908.

SIR,

I have the honour to submit herewith the Report of the Geological Survey for the year ending 31st December, 1907.

It comprises a general report of the work accomplished, followed by the more detailed and special reports of the field officers on the results of the geological investigation and mapping of the different areas assigned to them.

I am, Sir,

Your obedient servant,

H. KYNASTON,

Director of the Geological Survey.

The Secretary,
Mines Department, Pretoria.

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I.

DIRECTOR'S REPORT

FOR THE YEAR 1907.

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AREA COMPLETED.

PUBLICATIONS.

(*a*) *Official.*

(*b*) *Unofficial.*

I.—DIRECTOR'S REPORT.

Distribution of the Field-Work.

The field-work of the Geological Survey during the year 1907 was distributed so as to continue the mapping, already completed up to the end of 1906, mainly on the two lines already laid down in previous reports. The principal objects were: (1) the tracing of the sub-divisions of the Transvaal System and associated rocks round the north-eastern margin of the Bushveld Igneous Complex from the Lydenburg into the southern Zoutpansberg District; (2) the extension of the mapping of the country west of Pretoria towards the western boundary of the Colony; and (3) the survey of some portion of the southern Transvaal that would include an area occupied by rocks belonging to the Witwatersrand System.

In pursuance of the latter object, Mr. E. T. Mellor was stationed in the Potchefstroom District during the latter half of the field-season, a considerable proportion of his time being devoted partly to the economic features of the district, and partly to the interesting structural phenomena more especially connected with the Witwatersrand and succeeding formations in the neighbourhood of Venterskroon. An accurate knowledge of the detailed geological features of this district was also considered desirable on account of the important questions arising in connection with water-supplies and irrigation works in this area, involving frequent geological enquiries from other Government Departments.

Mr. A. L. Hall spent the first part of the season in the mapping of portions of the Lydenburg and Zoutpansberg Districts in continuation of the work carried out by him during 1905 and 1906, while during the latter portion of the year he was occupied to the south and south-west of Rustenburg, so as to complete the south-western portion of the area included in the Rustenburg Sheet (No. 4). (See Index Map, Plate I.).

Dr. W. A. Humphrey completed the survey of the central and northern portions of the Rustenburg Sheet, together with a small area further north along the west side of the Crocodile River as far as the Klip Spruit, the object of the latter survey being to work out as far as possible the relations and structure of the rocks belonging to the Transvaal System, previously mapped by him near the junction of the Aapies and Crocodile Rivers.

In addition to the ordinary field-work of the Geological Survey for the year, a reconnaissance was undertaken during June and July by Mr. E. T. Mellor, in company with Mr. T. G. Trevor, Inspector of Mines, with work of an economic bearing as one of its principal features. The chief objects of this traverse were:—

(1) To make a general inspection of the geology of the district traversed with a view to gathering information useful in the future work of the Survey;

(2) To collect data in connection with, and if possible to settle, certain geological questions on which either no definite information was available, or about which contradictory opinions were held. These included the character of the geological formation of the Zoutpansberg and Blaauwberg, the nature and geological position of the sandstones of the Limpopo Valley, the presence of coal-measures, and the relationship of the rocks of the northern Transvaal to those of other parts of the Colony and to those of Rhodesia;

(3) To visit the more important mining and prospecting areas, and to examine the nature of the mineral deposits and their geological relations.

These objects were accomplished, and a detailed account of the observations made has already been published by the Mines Department, entitled "Report on a Reconnaissance of the north-western Zoutpansberg District." In the present report a short summary is given by Mr. Mellor of the principal geological results of the traverse.

General Review of Field-Work.

A general review of the field-work of the geologists for the year shows a steady progress in the mapping, while considerable additions have been made to our knowledge of the geological formations and structure of various parts of the country.

Mr. Mellor's detailed and careful work in the Potchefstroom District has, among other questions dealt with, thrown considerable light upon the probable causes which produced the complicated structure of that area, and has placed our knowledge of the stratigraphy of the Transvaal System on a level with that of the development of this system in other parts of the country, such as the Pretoria, Rustenburg, and Lydenburg Districts, where it has been mapped in detail by Messrs. Hall and Humphrey.

Mr. Hall's studies of the metamorphic phenomena occurring in the Pretoria Series of the Lydenburg District have an important bearing upon the problems connected with the intrusion of the Bushveld Igneous Complex and the earth movements which were doubtless associated with it. Further, it is satisfactory to note the definite recognition of true volcanic rocks over extensive areas in the middle portion of the Pretoria Series, more especially since a considerable development of somewhat similar volcanic rocks have lately been described from the middle portion of the Griqua town beds of north-western Cape Colony, of which the Pretoria Series are now generally accepted as the Transvaal equivalent.

In the northern Transvaal, Mr. Mellor has recognised the sandstones of the Limpopo Valley as identical with the fine-grained sandstones of Buiskop, the Springbok Flats, and the Komatipoort Coal-field—now known as the Bushveld Sandstone Series; and the Tuli Amygdaloid, which overlies the Limpopo Beds, as the equivalent of the Bushveld Amygdaloid.

In the Annual Report for 1905 attention was drawn to the very close parallel between the Bushveld Sandstone Series of the Transvaal, with its fine-grained massive sandstones underlain by red marls and shales and overlain by thick flows of amygdaloidal basalts, and the Red Beds, Cave Sandstone, and Volcanic Group of the Stormberg Series of Cape Colony, but definite correlation was not considered advisable without more direct evidence. In April of last year an opportunity for a more direct comparison was afforded me by a short visit to Lady Grey, in the north-eastern Cape Colony, where remarkably clear and typical sections of the Stormberg Series can be examined. From the combined stratigraphical and lithological evidence collected during this examination,* the conclusion that the Bushveld Series of the Transvaal was of Stormberg age was considered to be fully justified, and it is satisfactory to find that this conclusion was confirmed by the discovery by Mr. Mitford Bowker of reptilian bones, determined by Dr. Broom as of Stormberg age, in the sandstones of the Limpopo Valley.†

The following correlation, therefore, of the sub-divisions of the upper portion of the Karroo System of the Transvaal may now be considered as established, and to this may be added the probable Rhodesian equivalents of the Transvaal formations from the data supplied by Mr. Mellor's work along the Limpopo,‡ combined with the observations further north of Rhodesian geologists §:—

TRANSVAAL.	RHODESIA.	CAPE COLONY.	
Bushveld Amygdaloid ..	Tuli Amygdaloid .. .. / Batoka Basalts	Volcanic Group ..	Stormberg Series.
Bushveld Sandstone Series ..	Samkoto Series .. .. / Forest Sandstones, and Klaballa Sandstones .. (Bechuanaland Protectorate)	Cave Sandstone .. / Red Beds	Stormberg Series.

Economic Geology.—With regard to *Economic Geology*, a preliminary examination was made by the Director, towards the end of the year, of the important deposits of cassiterite worked on Zaaiplaats and some of the neighbouring farms, situated to the north-west of Potgietersrust. Valuable information was collected by Mr. Mellor in the course of his work in the Potchefstroom District, concerning the "banket" reefs of the Witwatersrand Beds in the Venterskroon area. The Haenertsburg Gold-fields were examined and mapped by Mr. Hall, while the same geologist gives a detailed description of the gold occurrences, both alluvial and reef, in the area to the west of Krugersdorp. Messrs. Hall and Humphrey's work has also added very considerably to our knowledge of the chromite deposits of the Lydenburg and Rustenburg Districts. In the northern Zoutpansberg, considerable attention was paid to the composition and relationships of the ancient diamondiferous gravels worked at the Seta Mine, and to the copper deposits of Messina and M'Tamba, a full account of which will be found in the report by Messrs. Mellor and Trevor already referred to.

---

* H. Kynaston—"Note on the correlation of the Bushveld Sandstone Series and overlying Volcanic Rocks." Trans. Geol. Soc., S.A., vol. x, p. 31.

† See Proc. Geol. Soc. S.A., accompanying vol. x, p. 34.

‡ "Report on a Reconnaissance of the N.W. Zoutpansberg District." Part ii, p. 31.

§ A. J. C. Molyneux—"A Contribution to the Geology of the Bechuanaland Protectorate." Proc. Rhodesia Sci. Assoc., vol. vi, part ii, p. 86.

The water-supply from the Dolomite formation, always a subject of particular interest to this country, is dealt with in a special section of Mr. Mellor's report on the Potchefstroom District, while Dr. Humphrey gives some interesting details and suggestions regarding the somewhat peculiar features of the water-supply along the northern slopes of the Magaliesberg in the Rustenburg District.

Summary of Chief Results.-- It will be convenient to give here a brief summary of the chief results of the mapping for the year, according to the different districts over which it was distributed.

(1) *Potchefstroom District.*

Mr. Mellor's work in this area consisted mainly in the mapping of some 1,070 square miles, constituting the central portion of the district, in connection with which 1,910 miles of geological boundary lines were traced upon the field-maps, a proportion of nearly two miles of boundary lines to each square mile of area.

The district, which includes nearly all the formations known to occur in the Transvaal with the exception of the Waterberg System, was found to present great variety and complexity from a geological point of view, the amount of which is further increased by the unusual degree to which the Pretoria Series in particular has been subjected to earth-movements, and by the highly faulted condition of the over-tilted strata of the older rocks of the Ventersdorp and Witwatersrand Systems in the area round the Vredefort granite. It was found necessary, therefore, to carry out the mapping in considerable detail, so that the structural and stratigraphical features should be indicated as fully and as clearly as possible.

The area mapped by Mr. Mellor includes the greater portion of one of the sheet maps, which are being issued separately from time to time by the Geological Survey. In order, however, to avoid unnecessary duplication in the printing of maps, the publication of this portion of the Potchefstroom District will be deferred until the sheet in which it is included is completed, probably until shortly after the publication of the present Report. The incompleted portion of this sheet includes on the north-west a small area occupied by the Witwatersrand and Ventersdorp Systems, and forming part of the Klerksdorp Gold-field. It has been considered advisable, therefore, that the detailed description of the same systems as developed near Venterskroon, the main features of which have already been mapped, should also be deferred until the completion of the sheet, in order that a comparison of the two areas may be made, and uniformity of treatment as far as possible secured.

(2) *Rustenburg and Portions of northern Potchefstroom and north-western Witwatersrand Districts.*

In the early part of the field-season, Dr. Humphrey mapped a small area on the west side of the Crocodile River, between the Klip Spruit and the Elands River, following the western extension of rocks belonging to the Transvaal System, from near the junction of the Crocodile and Aapies Rivers. These rocks consist of quartzites of the Black Reef Series and Dolomite, succeeded by banded ferruginous quartzites, shales, quartzite and diabase, belonging to the Pretoria Series. They form an anticlinal fold, whose axis trends towards the north-west and are surrounded on all sides by the Red Granite. Felsitic rocks and breccias occur on Kruidfontein (147), overlying the banded quartzites, and probably belong to the Volcanic Series of the Lower Waterberg.

In the area further south, comprising the greater portion of the Rustenburg Sheet and including also small portions of the Witwatersrand and Potchefstroom Districts, Messrs. Hall and Humphrey completed an area of approximately 2,190 square miles, with 1,660 miles of geological boundary lines. Throughout this area the Pretoria Series is mainly in evidence, succeeded on the north-east by the Norite and Red Granite of the Bushveld. The sub-divisions of this series, mapped out further east, were found to continue westwards with remarkable persistence, though the Magaliesberg and Daspoort Quartzites become considerably reduced in thickness. The strike of the whole series gradually bends round to the north in the western portion of the area, so as to form a wide, almost semi-circular curve, while the dip of the beds is usually at a very low angle. Folding occurs in the Magaliesberg horizon and is well seen south-west of Rustenburg, where the escarpment of the main ridge forms the southern limb of a syncline followed to the north by a well-defined anticline.

The most interesting feature observed is perhaps the well-marked contact metamorphism of the shales, those of the upper Magaliesberg horizon having been converted into a cordierite contact-fels, and those of lower horizons into andalusite and chiastolite slates. Mr. Hall found that these contact phenomena are identical with those observed by him in the Lydenburg District, except that the effect of pressure metamorphism is scarcely noticeable in the Rustenburg area.

The so-called "vesicular diabase," occurring a short distance below the Daspoort Quartzite, hitherto mapped as an intrusive sheet, has now been recognised as a contemporaneous volcanic rock, and provisionally classed as a hornblende-andesite.

The norite attains an extensive development in this area, and includes the usual types already noticed further east. Its most interesting feature is the occurrence near its southern margin of bands of chromite, associated with basic varieties of norite and pyroxenites.

Dykes of elaeolite-syenite have now been followed for considerable distances across this area in a general north and south direction. Their general trend towards the Pilandsberg and gradual increase in number in that direction would appear to indicate a connection between them and the larger intrusions of syenite known to exist in that area.

In connection with the water-supply, Dr. Humphrey has collected some interesting details regarding the succession of powerful springs which rise along the upper northern slopes of the Magaliesberg. Obviously the water of these springs must be mainly derived from a subterranean source, and it has been suggested that their supply is maintained from the underground water in the Dolomite formation, which underlies the Pretoria Series and occupies a more elevated area further south than the site of the Magaliesberg springs.

In the Krugersdorp–Blauwbank area, Mr. Hall made an examination of the principal occurrences of gold, which occur a short distance above the horizon of the Timeball Hill or lowest quartzite of the Pretoria Series, in alluvial deposits and quartz reefs, the latter lying sometimes parallel to the bedding-planes of the shales, and sometimes cutting across them. Mr. Hall notes a general resemblance between these reefs and those of the Dolomite near Pilgrims Rest, though the latter are by far the more important from an economic point of view.

Plate X shows the geological features of the area where the above reefs and alluvial deposits occur. The map illustrating the geology of the area further north, however, described in the reports of Messrs. Hall and Humphrey on the south-west portion of the Rustenburg District and the neighbourhood of Rustenburg respectively, is published separately, with a short Explanatory Memoir, as Sheet 4 (Rustenburg).

(3) *Lydenburg and Portion of southern Zoutpansberg Districts.*

In these districts Mr. Hall mapped an area of 1,366 square miles, occupied mainly by the Transvaal System. He found that the general change in the strike of the system is marked by a number of sub-parallel oblique faults, while folding is also noticeable, more especially in the upper part of the Dolomite and base of the Pretoria Series. The leading quartzite horizons of the latter are still maintained as far as the mapping has progressed, though that of the Timeball Hill is finally reduced to a single band, often without its typical magnetic character, while below this horizon the normal basement shales pass into ferruginous quartzitic slates. A zone of banded ferruginous quartzite can also be followed for some distance in the upper part of the Dolomite.

Intense contact metamorphism was observed in the shales of the higher horizons of the Pretoria Series, two distinct types being at first easily distinguished. Towards the north, however, the influences of pressure metamorphism have evidently been combined with the contact action of the igneous masses of the Bushveld, and a third type has been produced, the members of which resemble true crystalline schists, the shales being converted into cordierite-bearing para-gneisses. The quartzites also are foliated and show metamorphic minerals.

Interbedded volcanic tuffs, similar to those already noticed by Mr. Hall further south, were mapped in the Pretoria Series over a distance along the strike of over thirty miles.

Chromite deposits, of the same character and association as those of the Rustenburg area, occur as well-defined bands alternating with pyroxenite, and can be followed for a considerable distance along the lower or eastern portion of the norite zone.

Area Completed.

The following table indicates the total areas in square miles completed by the geologists during the year together with the number of linear miles of geological boundary lines traced upon the field-maps :—

	Square miles surveyed.	Boundary lines traced.
E. T. Mellor (*Geologist*)	1,071	1,910
A. L. Hall (*Geologist*)	2,230	1,717
W. A. Humphrey (*Geologist*)	1,614	1,167
Totals	4,915	4,794

It will be seen that the total area mapped, namely, 4,915 square miles, falls only a very little short of the area completed during the preceding year, which amounted to 4,964 square miles, part of the mapping during 1907 having involved rather more detailed work. This is shown by a comparison of the number of miles of geological boundaries traced during each of these two years, namely 4,798 during 1906, and 4,704 during 1907, the proportion of boundary lines to area being somewhat higher for the latter year.

The number of miles travelled in the course of the mapping and traversing of the above areas was as follows :—

	By Wagon.	Driving, riding, and walking.
E. T. Mellor	680	2,800
A. L. Hall	445	2,297
W. A. Humphrey	635	2,269
TOTALS	1,760	7,366

PUBLICATIONS.

(*a*) *Official.*

1. *Maps.*—The following maps were published during the year on the scale of 2·35 miles to one inch, and illustrated by horizontal sections :—

Portions of the Pretoria and Witwatersrand Districts, illustrating the southern portion of the Pretoria-Johannesburg Granite.

Portion of the Lydenburg District, between Lydenburg and the Oliphants River.

Portions of the Lydenburg and Carolina Districts, lying north and south of the Delagoa Bay Railway between Belfast and Machadodorp.

Portions of the Pretoria and Middelburg Districts, including the neighbourhood of the town of Middelburg.

Portions of the Pretoria, Rustenburg, and Waterberg Districts, lying on the east side of the Crocodile River.

Portions of the Rustenburg and Witwatersrand Districts, illustrating the Pretoria Series south-east of Rustenburg.

The following sheets of the Geological Map of the Transvaal were also published during the year :—

Sheet No. 1, Pretoria.
„ 2, Pienaars River.
„ 3, Middelburg.

2. *Memoirs.*—"The Geology of the Country surrounding Pretoria"; an explanation of Sheet No. 1 : by the *Director*.

"The Geology of a Portion of the Bushveld, north of Pretoria"; an explanation of Sheet No. 2 : by the *Director*.

"The Geology of the Neighbourhood of Middelburg, and of the Country westwards, as far as Bronkhorst Spruit"; an explanation of Sheet No. 3 : by E. T. Mellor (*Geologist*).

(*b*) *Unofficial.*

The following unofficial contributions by members of the staff to scientific societies, etc., were published during the year :—

H. Kynaston .. .. "Note on the Correlation of the Bushveld Sandstone Series and the Overlying Volcanic Rocks." Trans. Geol. Soc., S.A., Vol. X, pp. 31–35.

„ .. .. "The Marginal Phenomena and Geological Relations of the Granite north of Johannesburg." Trans. Geol. Soc., S.A., Vol. X, pp. 51–61.

E. T. Mellor .. .. "Note on the Field Relations of the Transvaal Cobalt Lodes." Trans. Geol. Soc., S.A., Vol. X, pp. 36–43.

„ .. .. "The Geological Structure of the Middelburg District, with special reference to the character, relationships, and thickness of the Waterberg System." Trans. Geol. Soc., S.A., Vol. X, pp. 44–50.

II.

THE GEOLOGY OF THE CENTRAL PORTION OF THE POTCHEFSTROOM DISTRICT.

By E. T. MELLOR (*Geologist*).

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II.—THE GEOLOGY OF THE CENTRAL PORTION OF THE POTCHEFSTROOM DISTRICT.

By E. T. Mellor (*Geologist*).

1. Area Surveyed.

The area dealt with in the present report comprises the central portion of the Potchefstroom District, the town of Potchefstroom lying approximately in the centre. It is included in Sheet No. 5 of the Geological Map to be issued by the Survey and to which reference should be made. The area, which is roughly rectangular in shape, is bounded on the south by the Vaal River, on the west by a line following approximately the course of the Koekemoer Spruit, on the north by a line running a little to the north of Boskop Station eastwards as far as the Losberg, and on the east by a line from the Losberg to near Lindeque's Drift. The survey was carried out during the months of October to December, 1907. The area mapped embraces 1,071 square miles, with 1,910 miles of geological boundary lines, or 1·78 miles of boundary line to each square mile of area, a proportion larger than usually mapped, chiefly owing to the considerable amount of detail shown by the highly tilted, and frequently much folded, strata of the Transvaal System in this area. The topographical maps used as a basis for the geological work have been the "Degree Sheets" issued by the Surveyor-General's Department, while within a certain radius of Potchefstroom, a map prepared by the military authorities has been found of great assistance. As far as possible the geological lines have been mapped with reference to farm beacons.

Of the area defined above that occupied by the formations younger than the Ventersdorp System has been completed, and these formations are described in detail in the present report. In addition to this work, the main features of the area occupied by the Ventersdorp and Witwatersrand Systems was also examined, and the main outlines of its geology were mapped with a view to subsequent work during the next field-season, in greater detail and on a larger scale than that advisable in the general mapping of the country.

On account of the economic importance of the older systems referred to and the interesting tectonic features shown by the district, the Venterskroon area has attracted a good deal of attention from geologists and others. Diverse opinions, however, prevail on several important points, and the solution of the questions involved can probably only be accomplished as a result of a very detailed survey, and comparison with occurrences of similar rocks in other parts of the Transvaal.

2. Physical Features and General Geological Structure.

The district under review presents considerable variety with regard to the geological formations which occur within it, which range from the Witwatersrand System up to the Coal-measures. All the main systems of rocks hitherto met with in the Transvaal, with the exception of the Waterberg System, are represented, and this diversity in the geology of the area is reflected to a certain extent in the character of its surface, although in this latter respect the district does not present so great a variety of features as might be expected from the broken and disturbed character of its geological structure.

Many of the surface features, for example, produced by the highly folded quartzites of the Pretoria Series are comparatively insignificant, and in some cases these quartzites are now represented by no surface features at all, a condition largely the result of very advanced denudation. This is particularly the case along the wide valley formed by the lower portion of the Mooi River and its tributary the Loop Spruit, both of which streams have practically reached a base level of erosion.

The general succession and disposition of the rocks in the Potchefstroom District will be best gathered from an examination of the general section on the same scale as the map shown in Plate VIII, taken from Parys in a straight line running N. 62 degrees W. (true bearing) to Potchefstroom, thence due west to Spitzkop, and from Spitzkop N. 70 degrees W. to the edge of the Black Reef on Eleazar (617). In the section the general synclinal arrangement of the whole area together with the subordinate folds in the Transvaal System is well seen, as are also the variations in the surface profile due to the different formations. Proceeding from S.E. to N.W. the main mass of the Vredefort granite, upon which Parys stands, is succeeded by the beds of the Witwatersrand System, the actual junction, however, being obscured by a very persistent intrusion of

an amygdaloidal diabase. The inversion of the Witwatersrand rocks, which on this line of section results in a dip of 70 degrees to the south-east, tends to increase towards the upper portion of the system. In the series of quartzites and conglomerates, which lie below the Ventersdorp amygdaloid, corresponding to that well known on Rooderand, the reversal of the dip is usually considerably greater than in the quartzites between these and the lower portion of the Witwatersrand System, an effect which may be due either to faulting or to unconformity. The junction between the same quartzites and this Ventersdorp amygdaloid also shows in places a considerable degree of faulting.

The section from the Ventersdorp amygdaloid through the Black Reef to beyond the lowest quartzite of the Pretoria Series also shows complete reversal, more normal conditions prevailing in the wide valley of the Loop Spruit, in which Potchefstroom stands, where the Pretoria Series forms a broad syncline. Between the syncline and the reversed section near the amygdaloid, a faulted anticline occurs in the line of section, which brings the conglomerate near the base of the Pretoria Series to the surface on Rooipoortje (278). South of the line of section on Roodekraal (678), a position, corresponding to that of the faulted anticline just referred to, is occupied on Roodekraal by a big igneous intrusion, on the north-western side of which the quartzites of the Pretoria Series still show a reversed dip.

West of the town of Potchefstroom the Dolomite is brought to the surface by a somewhat sharp anticline, while Spitzkop occupies the axis of a broad syncline whose western limb shows dips falling to 10 degrees on Eleazar, where the Black Reef rests upon the Ventersdorp rocks, which are underlain in turn by those of the Witwatersrand System.

If a general view be taken of the geology of the district it is seen that it shows a very marked concentric arrangement of the successive geological formations, the outcrops of which form successive curved zones disposed around the central granite mass of Vredefort and Parys. This concentric arrangement is exceedingly well marked, both geologically and physically in the neighbourhood of the Vaal River, and in those geological horizons included between the granite and the base of the Pretoria Series. It can, however, be easily traced throughout the remainder of the area and in the country immediately to the north, the range of the Gatsrand and its south-westerly continuation to the north-west of Potchefstroom conforming to the general concentric arrangement ; although the fact is here less evident than is the case nearer the Vaal River.

The arrangement of the sedimentary formations in the form of a syncline whose axis is a curve approximately concentric with the margin of the Vredefort granite is attributed by Molengraaff * to pressures acting in a radial direction due to the intrusion of the Vredefort granite. While, however, the granite, if intrusive, may have been an agent in the early stages of the disturbances, which the Witwatersrand System and overlying rocks have undergone, it seems probable that the complete overtilting of the system is due to the effects of long continued subsequent pressures from outside, combined with the resistance offered by the granite boss. Mr. E. Jorissen,† in explaining the curvature of the strike of the Witwatersrand System in passing from the Rand area towards Klerksdorp, attributes it to a pressure originally acting directly from the north towards the south, and modified by the resistance of the Vredefort granite boss into forces acting in directions parallel to radii of the curves shown by the outcrops of the sedimentary systems.

It will be convenient to follow this zonal arrangement, shown by the different geological formations, in describing the district commencing from the central granitic area about Parys, and passing outwards over the successive concentric belts of country.

Of the granitic area only a comparatively small portion is included in the Transvaal immediately north of Parys, the greater portion lying on the south side of the river. Taken as a whole this extensive granitic area forms a wide tract of comparatively level or gently undulating country, extending far into the Orange River Colony, and merging southwards into similar country occupied by the rocks of the Karoo System. Viewed from the heights about the Vaal, this gently undulating country extends in all southerly directions as far as the eye can reach, broken only by occasional isolated hills. It forms a striking contrast to the hilly and broken character of the greater part of the country lying to the north of the river in the Transvaal.

Into this comparatively low-lying and level country the Vaal River emerges from among the high quartzite ridges lying to the north-east of Parys about the farm Brakfontein (673), and after a short excursion into the granitic area re-enters the mountains on Koppieskraal. Everywhere along its northern margin the granitic area is bounded by a broad zone of very broken and hilly country consisting of a number of parallel ranges formed by the highly inclined quartzites of the Witwatersrand System. The comparatively low granite country rises in a series of gentle undulations to the foot of the first escarpment which usually forms a

* Trans. Geol. Soc., S.A., vol. vi, 1903, p. 24.
† Trans. Geol. Soc., S.A., vol. ix., 1906, p. 52.

Plate II.

The Vaal River at Venterskroon, showing ridges of the Witwatersrand beds on the left.

conspicuous feature, behind which several successive ranges rise to an elevation of from 600 to 1,000 feet above the level of the Vaal River. Notwithstanding their very moderate height, the extremely rugged and broken character of these ridges, and the contrast they afford to the country to the south, give them a very imposing appearance, and this together with their geological structure justifies the name of " mountains " usually applied to them, the range being sometimes referred to as the " Vredefort Mountain Land." * Vredefort, however, lies at a distance of several miles from the mountainous zone, well out in the granite area, as also does Parys. On the Transvaal side of the river, however, the village of Venterskroon lies right in the heart of the mountainous country and forms a good centre for its investigation.

The immediate neighbourhood of Venterskroon is justly well known for its attractive scenery, and is frequently visited by Potchefstroom people. The quartzites of the Witwatersrand System here give rise to numerous closely ranked parallel ranges which rise some seven or eight hundred feet above the river, and whose bold outlines are only partially concealed by the thin covering of sugar-bush, by which they are usually clothed, and which gives place on the lower slopes and along the valley bottoms to a moderately thick growth of unusually fine thorn trees which give the country a well wooded aspect. The most striking feature, however, of the Venterskroon country, and one which is unfortunately too rare throughout the greater part of South Africa, is the association of mountain scenery with fine stretches of water formed by the wide reaches of the Vaal River, which traverses the greater part of the mountain region (Plate II). For some miles above and below Venterskroon the Vaal follows one of the main depressions between the parallel ranges, corresponding approximately to the divison between the lower and upper portions of the Witwatersrand System. This wide depression is followed by the river from Koedoeslaagte above Venterskroon as far as Schoeman's Drift below, a distance of some twelve miles. Above Koedoeslaagte the same depression is continued to the north-east as far as the western boundary of Buffelshoek (629). Beyond this point a well marked depression continues eastwards over the southern corner of Buffelshoek and the northern corner of Rietpoort (649), beyond which it opens into a broad valley extending across the northern portion of Brakfontein (673) as far as the Vaal. The apparent correspondence of the depression eastwards of Buffelshoek with the main depression to the west, of which it is topographically a continuation, suggests to an observer taking a general view of the locality, a correspondence also of geological horizons. Such a correspondence, however, does not exist. Owing to very extensive faulting the horizon of the Venterskroon Valley is interrupted near the west boundary of Buffelshoek, and is represented further east by a depression at the same geological horizon which recommences about the middle of Buffelshoek, and continuing eastwards is traversed in part by the old main road leading from Potchefstroom to the old Viljoen's Drift.

The feature just referred to, which includes the valley of the Vaal River from Koedoeslaagte to Schoeman's Drift, corresponds approxim tely to the horizon between the Lower and Upper Series of the Witwatersrand System, the quartzites of which give rise to the prominent parallel ranges which run on both sides of the river about Venterskroon, and are continued north-eastwards beyond Koedoeslaagte. The quartzites of these ridges are inclined at high angles of 50 degrees and upwards, and dip almost universally south-eastwards towards the granite mass of Vredefort, the whole system thus showing a complete reversal. In the Lower Series, lying nearer to the granite, the predominance of shales (see Section, Plate VIII) is reflected in the topography in the greater width of the valleys and the sharper character of the parallel quartzite ridges, of which as many as five may be present. In the Upper Series, the almost entire absence of shales and the great thickness of the quartzites give rise to the broad and massive outer ridges which extend along the north-western bank of the Vaal from Schceman's Drift to Koedoeslaagte, and continue thence by Buffelshoek on to the northern portions of Witkop (402). It may be noted that while for some miles above and below Venterskroon, the Vaal River follows a longitudinal valley parallel to the strike of the Witwatersrand System, in other places it breaks transversely through the ranges, giving rise to a somewhat different type of scenery. Thus some six miles below Lindequee's Drift the river traverses the whole breadth of the Witwatersrand System on Witklip and Brakfontein, and after its passage through the hills emerges to flow for some distance through the low granite country of Parys. Re-entering the ranges on Koppieskraal (284) it again crosses the Lower Witwatersrand Series, and turning south-eastwards flows past Venterskroon to Schoeman's Drift, where it breaks abruptly through the ranges formed by the Upper Witwatersrand rocks, and by the amygdaloid of the Ventersdorp System, to pass into the less varied country occupied by the Dolomite and Pretoria Series to the west.

Very fine and extensive views of the mountainous country about Venterskroon can be obtained from the summits of the numerous ridges. On the Transvaal side one of the best positions for obtaining a good general view both of the physical and geological features of the district is the high ridge of white quartzite upon which

* G. A. F. Molengraaff, " The Vredefort Mountain Land," Trans. Geol. Soc., S.A., vol. vi, 1903.

stands the most southerly beacon of the farm Koedoesfontein (12), about eight miles east of Venterskroon. This point commands a fine panorama of the whole stretch of the Vaal River from the big bend on Buffelskloof to Parys. Eastwards the parallel ranges formed by the quartzites of the Lower Witwatersrand Series can be followed far beyond the Vaal, while to the west the observer looks right into the heart of the broken country formed by the same rocks to the south of Venterskroon. Northwards the wide sweep of the big ridges formed by the massive quartzites of the upper portion of the Witwatersrand System is well seen, and can be followed from beyond Venterskroon on the west to near Viljoen's Drift on the east.

Perhaps the most striking feature in the extensive views obtained from the mountains about the Vaal River is the marked contrast presented by the wide expanses of comparatively level country, broken only by occasional isolated hills, which stretch southwards as far as the eye can reach into the Orange River Colony, as compared with the more broken and hilly character of the Transvaal to the north.

Outside the very rough and hilly zone occupied by the Witwatersrand System, and between it and the low-lying Dolomite zone, lies that occupied by the volcanic rocks, mainly amygdaloidal diabase of the Ventersdorp System. These rocks occupy a well marked belt of country, of a very uniform breadth of about three and a half miles, easily recognised by its physical characters.

It rises into broad swelling hills forming a more or less continuous range extending in a south-easterly direction from near Lindequee to beyond De Wet's Drift, and constituting the watershed between the tributaries of the Loop Spruit and Mooi River, and the smaller streams flowing southwards to join the Vaal more directly. These hills reach a considerable elevation, only slightly below that of the massive quartzite ridges of the Witwatersrand System. They are usually broadly rounded at the top, very smooth in outline, and without any prominent surface features. Viewed from a distance the hills of amygdaloid appear uniformly grass-covered, small trees only occasionally occurring as isolated individuals, or in widely separated groups of two or three. The rock, however, is always close to the surface, forming occasionally more or less conspicuous outcrops.

The surface soil, instead of the usual red, resulting from the decomposition of diabases, is of a yellowish brown colour, and frequently covered with quartz fragments representing weathered-out amygdales. The grasses are shorter than usual, and of a somewhat wiry type.

The spruits which rise in the amygdaloid country are few in number and small in size, although usually rising in broad catchment areas. Such streams as exist are, however, fairly permanent in character.

Where the high ground of the amygdaloid falls to the lower zone characteristic of the Dolomite, the approximate junction of the two can usually be distinguished even from a distance by the change from the bare grassy uplands of the one to the comparatively well wooded hollows of the other.

The continuous zone of Dolomite, which extends in a wide curve from the Vaal at Lindequee to cross the river again at De Wet's Drift, sixteen miles due south of Potchefstroom, like the zones already referred to, has a characteristic effect upon the surface topography. It forms a belt of country usually lying at a comparatively low level between the broad hills of the amygdaloid on the one hand, and the sharp ridges and escarpments of the quartzites of the Pretoria Series on the other. As a rule the country is thickly grassed, and dotted over at intervals with small but dense clumps of trees. These are frequently particularly numerous and tend to form a continuous and thick belt of timber along the outcrop of the Black Reef along its junction with the amygdaloid, a feature especially noticeable where the junction is crossed by the main road from Potchefstroom to Venterskroon. On account of the general absence of surface streams, a feature very characteristic of all Dolomite areas houses are rarely seen on this zone, although a marked exception to this is to be found to the west of Lindequee, where the combination of the good water-supply found along the course of the Bronkhorstfontein Spruit with the natural richness of the Dolomite soil, has led to unusually close settlement along this valley.

Although the Dolomite area usually forms comparatively low-lying country, certain portions of it, in which strong bands of chert form a prominent constituent of the rock, frequently give rise to small but prominent ridges and kopjes, distinguished by the extreme roughness of the outcropping chert and its debris. Such ridges are most abundant near the junction of the Dolomite with the Pretoria Series where, on the uppermost portions of the Dolomite, cherty beds are strongly developed.

In the eastern portion of the area in the neighbourhood of the Vaal River on the farms Eigenaarsfontein (596), Modderfontein (403), Bronkhorstfontein (30), and Zeekoefontein (21), several extensive caverns are known in the upper and cherty portion of the Dolomite. Such caverns are probably of frequent occurrence throughout the whole formation, being frequently indicated by extensive subsidence of the surface, but are more likely to be discovered in the cherty zones owing to the massive chert beds preventing the complete filling in of the entrances. A further reference to these caverns will be found in the section dealing more particularly with the Dolomite.

The outer edge of the Dolomite zone is usually marked by conspicuous ridges formed partly by the thick beds of resistant chert occurring near the top of the formation, and partly by the lowermost quartzite of the Pretoria Series. These form an almost continuous line of ridges, usually double in character, extending from Lindequee's Drift to near De Wet's Drift. The ridge forms one edge of the very wide belt of country occupied by the Pretoria Series.

This belt, which has an average width of 15 to 20 miles, forms a broad syncline, with many minor synclines and anticlines, lying between two parallel belts of Dolomite country as shown on the map. From that on the south it is separated by the ridge above alluded to, while its northern edge is formed by the prominent and well-known range of the Gatsrand, which lies a little beyond the limits of the area included in the present description. The Gatsrand, which forms so prominent and continuous a feature in the country between Johannesburg and Potchefstroom, is interrupted to the north of the latter town by the extensive folding, which brings in a tongue of the Dolomite to the west of the railway. Beyond this interruption the range is, however, continued from Witstinkhoutboom towards the south-west as a pronounced line of hills as far as the railway at Machavie, beyond which point the quartzites at the base of the Pretoria Series cease to give rise to any conspicuous surface features, although the upper portion of the Dolomite is usually represented by prominent ridges as far as the Vaal.

The broad belt of country occupied by the Pretoria Series shows more diversity within its limits than the other zones already referred to. Geologically the series consists for the most part, as elsewhere in the Transvaal, of shales and intruded diabases, with quartzites well developed at three different horizons. The shales and diabases usually form the valleys and depressions, while the quartzites give rise to more prominent surface features, usually in the form of sharp and well defined ridges. Where, however, the quartzites are very highly inclined, or vertical, they frequently give rise to no surface features at all, while on the other hand, if horizontal, or nearly so, they produce broad flat-topped hills of the "Tafel-kop" type—such as the Losberg in the north-eastern part of the area at the head of Loop Spruit, Paardekop to the east of Boskop Station, and the small raised plateau to the south of Potchefstroom on the farm Plessieskraal (529). On the north side of the zone occupied by the Pretoria Series only two quartzite ridges are usually developed, that of the Gatsrand and an accompanying ridge to the south of it, while along the southern margin of the zone the quartzites, many times repeated owing to a complicated series of folds, give rise to several roughly parallel ridges whose distribution will be best understood by reference to that of the corresponding quartzites on the map. In some instances the folding of the quartzites causes their outcrops at the surface to give rise to prominent ridges disposed in circular fashion, which form a somewhat peculiar feature in the topography of the district. Examples of these curved ridges are those indicated by the quartzites shown circling round the S.W. beacon of Enzelpoort (601), on Syferfontein (584), and on the western boundary of Elandsheuvel (589).

Between the ranges of hills formed by the quartzites on the northern and southern margins of the broad belt occupied by the Pretoria Series, a particularly wide and open valley extends for nearly forty miles from Losberg, south-westwards to the junction of the Mooi River and the Vaal, and has an average width of about eight miles. Near the middle of its length lies Potchefstroom. This valley, which forms one of the main physical features of the area, approximately coincides with the axis of the big syncline in the Pretoria Series. It is traversed in the upper portion by the Loop Spruit, and in its lower portion by the joint stream of the Loop Spruit and the Mooi River, which above the junction, occupies a much less conspicuous valley than that of its tributary.

The fine perennial stream of the Mooi River, which determined the position of the earliest settlement in the Transvaal and of the ancient capital Potchefstroom, is derived almost entirely from strong springs in the Dolomite, and is many times greater than the ordinary discharge of Loop Spruit. The relative sizes of the valleys of the Mooi River and Loop Spruit, however, probably correspond more nearly to the volumes of surface water brought down by each from their respective catchment areas, and are more nearly a measure of the relative denuding power of these streams in past times. Both main valley and that branch of it traversed by the Klein Loop Spruit or Rooikraal Spruit are remarkable for the broad extent of almost flat land which occupies the greater portion of the valley.

For a breadth of from a half to five miles the slopes of the valley are almost entirely covered with surface deposits of a partially alluvial character which merge imperceptibly into the true alluvium and black soil of the flats bordering the main streams. Much of the ground thus covered is under cultivation, and a considerable proportion is irrigated. The extent of these surface deposits has been shown on the map, and their character is again referred to later. Both the Loop Spruit and the Mooi River below Potchefstroom have a very low gradient and pursue meandering courses between steep banks of alluvium many feet in depth. The erosive powers of these streams is practically *nil*, and the whole aspect of the broad valley which they traverse

is that of one which belongs to a drainage system which has almost attained a base level of erosion. The upper portion of the valley of the Loop Spruit is dominated by the Losberg which is visible from about Potchefstroom. This broad flat-topped mountain consisting of two detached portions is one of the most conspicuous features of the district. It lies between two arms of the Loop Spruit and is a typical example of circum-denudation. It lies on the axis of the main syncline on the Pretoria Series and consists for the most part of beds of the uppermost quartzites, which, dipping at low angles towards the centre of the mountain, have successfully resisted the denuding forces which have excavated the broad valley in which it stands.

Of similar structure and origin is the hill known as Spitzkop which from its symmetrical shape forms a conspicuous and easily recognised landmark to the west of Potchefstroom. This Kop like the Losberg occupies the centre of a synclinal fold in the Pretoria Series, the synclinal structure giving rise to a characteristic elevated area of about fifty square miles in extent, surrounded on three sides by the lower ground of the Dolomite. Around the margins of this area run the parallel ridges formed by the upper cherty beds of the Dolomite and the lowest quartzites of the Pretoria Series, within which extend the higher and broader ridges formed by the extensive sheet of amygdaloidal diabase which occurs at this horizon, and which rises at its northern extremity into the heights of Vaal Kop. In the midst of the lower ground in the centre of the syncline stands the miniature peak of Spitzkop consisting of a base of shales capped by the remains of the middle quartzites of the Pretoria Series. This small synclinal area around Spitzkop is cut off to the south by a series of faults, whose course corresponds with the depression followed by the Klerksdorp railway line between Potchefstroom and Machavie.

The Outer Zone of Dolomite.—To the north and west of Potchefstroom, beyond the margin of the Pretoria Series, lies a second zone of Dolomite, similar in character to that already described to the south-east of the town. The Dolomite here occupies a belt of country varying in breadth from three to nine miles, extending from near Boskop Station to the Vaal, near the mouth of the Koekemoer Spruit. This country forms a comparatively low, gently undulating, tract thickly grassed and dotted over with small clumps of bush, rising on either margin to the higher ground occupied on the one side by the ridges of the Pretoria Series, and on the other by those of the Ventersdorp or Witwatersrand Systems, the former as a rule being but poorly represented in the locality. The Dolomite country shows the usual scarcity of surface streams. From Rietkuil (537) southwards to the Vaal, it is traversed by the valley of the Kromdraai Spruit, which however is dry during the greater part of the year, with the exception of a short section near the Vaal on Haartebeestfontein (573). Strong springs issue near the banks of the spruit on the centre of this farm, but after flowing some distance the water again disappears below the surface.

The tongue of Dolomite country which extends southwards from Witstinkhoutboom (146) and Koloniesplaats (25) differs in many ways from the main body. It is traversed in part by the fine stream of the Mooi River, the narrow alluvial flats under irrigation along the banks being among the most productive land in the Transvaal. Several strong springs are discharged into the Mooi River along this portion of its course. From Witstinkhoutboom southwards the tongue of Dolomite frequently rises into rough ridges of considerable elevation which terminate near the railway to the south of Potchefstroom.

In the area under review the geological formations given below in ascending order are represented :—

The Older Granite.
The Witwatersrand System.
The Ventersdorp System.
The Transvaal System.
The Karroo System.

3. The Witwatersrand and Ventersdorp Systems.

As already stated in the introductory section the survey of the area occupied by these older systems is not yet complete. They will be dealt with in detail in a subsequent report when the mapping of the area has been completed.

In the general section shown in Plate VIII, which is given mainly to illustrate the structure of the area occupied by the Transvaal System, the general disposition and relationships of the Witwatersrand and Ventersdorp Systems have also been shown. In this section the big series of quartzites and conglomerates found on Rooderand near Venterskroon have been included in the Witwatersrand System. The Rooderand bankets are generally regarded as corresponding to the Elsburg Series of the Rand. If this correlation prove correct, the series would then probably have to be included in the Ventersdorp System, in accordance with the view, now widely held, that an unconformity exists between the Elsburg Series and the Witwatersrand System.

As pointed out by Molengraaff, the considerable difference in the amount of dip shown by the Rooderand quartzites, as compared with the series immediately below them, favours the idea of an unconformity, although the agreement in direction of dip over a very great distance along the strike is against this conclusion. Owing to the complete inversion of the whole succession of rocks in the Venterskroon area, it is unlikely that the conformable or unconformable nature of the relationship of the Rooderand beds to those which underlie them on the one hand, and to the Ventersdorp amygdaloid on the other, can be decided in this district. Considerable faulting has almost certainly taken place along the lines of junction, which in both cases also almost everywhere correspond with valley-like depressions, in which the underlying geology is usually completely masked by heavy deposits of surface drift.

4. The Transvaal System.

The Transvaal System occupies the major portion of the district under review. Although well represented as far as the area which it occupies is concerned, the system does not offer such good opportunities for study as in other parts of the Transvaal, sharing in the disturbed character which prevails throughout the rocks of the district, and few good natural sections occur.

As in other parts of the Transvaal, three main divisions of the system are represented as follows :—

	Approximate thickness.
Pretoria Series (shales, quartzites, and intrusive diabases)	13,000 feet
Dolomite (dolomitic limestone, chert, and shales)	5,500 „
Black Reef Series (conglomerates, quartzites, and shales)	60 „
Total	18,560 feet

(a) *The Black Reef Series.*

The Black Reef Series, which forms the basal portion of the Transvaal System and rests unconformably on the older rocks below, consists of a series of shales and sandstones or quartzites, associated with more or less definite beds of conglomerate, usually auriferous, from which the name of the series originated.

The Black Reef Series varies very considerably in thickness in various parts of the Transvaal. In the Potchefstroom District it is but poorly developed, probably nowhere exceeding 100 feet in thickness. Along the southern limb of the Potchefstroom syncline it is very feebly represented. Here the series rarely forms any conspicuous outcrop, such as is usual in other parts of the Transvaal. The formation is easily passed over without notice, and frequently makes no appearance at the surface for considerable distances along its strike. Although a little prospecting has been done on the Black Reef Series along this line, no actual mining has taken place, as in the case of the more northerly occurrences referred to below.

Exposures of the series occur at various localities along the strike, among which may be mentioned those on Bronkhorstfontein (30), Rietfontein (555), Haartebeestpoortje (533), Klipfontein (189), and De Wet's Drift (279). The Black Reef Series is well seen near the centre of Rietfontein (555), where it gives rise for a distance of two or three hundred yards to a miniature escarpment thickly covered with bush, on the northern side of a ridge which stands out a little from the main ridges of the amygdaloidal diabase on the south.

Taking the section exposed on the escarpment in conjunction with one seen in a small prospecting trench a little further east, the local sequence is approximately as follows :—

Dolomite, with included bands of shale	— feet
Black Reef Series—	
Dark grey shales	12 „
Conglomerate, with small and medium sized pebbles (½ to 3 in. diam.)	15 „
Shale and sandstone, with bands of small pebble conglomerate ..	12 „
Conglomerate, with small pebbles	6 „
Shale	3 „
Amygdaloidal Diabase..	— „
Total	48 feet

In the section given above the beds lie with a reversed dip of 10 degrees to the south. The thickness of the series is probably above the average for this locality.

Proceeding westwards the series is again well seen about the centre of Haartebeestpoortje along the main road to the west of the spruit, where several shafts have been sunk along the line of the conglomerate. An average section of the series in this locality appears to be as follows :—

Black Reef Series, Haartebeestpoortje (533).

Thinly laminated shales, rather soft, weathering to purplish, light grey, and lavender colours	25 feet
Conglomerate, with pebbles averaging ½ inch	1 „
Hard, thin bedded sandstones and shales	20 „
Amygdaloidal diabase	—
Total	46 feet

The beds are here again reversed and dip to the south-east at an angle of about 60 degrees. In these trenches and shafts the tendency of the beds to show at the surface a dip very much lower than the true one is frequently well seen. The surface dips shown by the harder outcropping beds of the series are everywhere liable to be very misleading.

Although no outcrop of the Black Reef Series appears where it is crossed by the road from Potchefstroom to Venterskroon, about a quarter of a mile east of the eastern beacon of Vogelzang (529), the series can be quite well seen about 300 yards south of the road on the edge of the thick belt of thorns which marks the edge of the Dolomite, and which fringes a low bult entirely devoid of trees, and composed of the Klipriversberg amygdaloid. The Black Reef outcrop here consists of a few beds of very hard bluish white quartzite, with thin bands and washes of pebbles, together with several more definite beds of conglomerate, consisting of small pebbles averaging about half an inch in diameter, composed mostly of rather cherty looking quartz or of dark coloured fine-grained quartzite. The beds have a dip of 60 degrees towards the east.

Towards De Wet's Drift outcrops of the Black Reef Series can frequently be seen and have been opened up in places by trenches. An outcrop can be seen on the banks of the river at the drift. In this neighbourhood the series consists of several strong beds of hard bluish white quartzites, alternating with light and dark green shales. With the quartzites are associated somewhat ill-defined bands of small pebbles from 2 to 4 inches in thickness. The dip, which varies between 65 and 80 degrees, averages about 70 degrees east.

Along the northern limb of the Potchefstroom syncline the Black Reef Series, although not attaining any very considerable thickness, shows a somewhat greater development than is the case along the southern limb, and presents an outcrop sufficiently conspicuous to be recognised without difficulty throughout the greater portion of its extent. It has also been prospected to a considerable degree, and many claims were formerly pegged out along the course of the Reef, especially in the neighbourhood of Eleazar (617). In this portion of the district the Black Reef Series usually lies upon the easterly slopes of the high ground formed by the older rocks of the Ventersdorp and Witwatersrand Systems, which overlooks the Dolomite from the west, and runs in a south-westerly direction from Welgegund on the northern margin of the map towards Klerksdorp. From Rietkuil (537) to Rietfontein (632) these slopes form the western side of the broad valley of the Kromdraai Spruit. The dip of the formation is towards the south-east at angles of from 10 to 15 degrees, increasing in places to about 25 degrees. At the point where it is crossed by the Kromdraai Spruit the Black Reef Series is faulted towards the west, the formation showing considerable disturbance for some distance to the north of this point, and assuming a highly inclined to vertical position for a short distance on the northern portion of Rietkuil (537).

On Eleazar the conglomerate is more conspicuously developed than elsewhere in the area described. It is from 5 to 6 feet in thickness at the outcrop, and consists of a dark bluish grey conglomerate, with pebbles averaging about 1 inch in diameter, but varying considerably in size, set in a somewhat scanty sandy matrix. The majority of the included fragments, which are frequently sub-angular in shape, consist either of a very finely crystalline to cherty translucent quartz, varying from light grey to nearly black in colour, or of a much more coarsely crystalline light grey quartz. Both of these probably represent amygdales derived from the underlying Klipriversberg amygdaloid, the cherty specimens occasionally consisting of hollow shells showing the concentric banded structure frequently found in such amygdales. Besides the pebbles mentioned above, there also occur a few composed of well-rolled fragments of quartzite, derived most probably from the quartzites of the Witwatersrand System. Pyrites occurs abundantly throughout the matrix of the conglomerate, both

in the form of cubical crystals and in nodular masses up to half an inch in diameter, which frequently present a smooth and water-worn appearance, possibly due to a pseudomorphic replacement of pre-existing small pebbles.

At the outcrop the conglomerate weathers to a brownish yellow, the pyrites giving place to oxides which give the rock a very ferruginous appearance. The cherty pebbles become a dull opaque white, the more coarsely crystalline fragments remaining unaltered. Northwards from Eleazar the conglomerates are not so well developed, and are frequently represented, as on Welgegund (84), by beds partaking more of the character of a breccia consisting for the most part of opaque white cherty fragments in a sandy matrix.

Besides the conglomerates, the Black Reef Series along that portion just referred to, as well as in many other localities, includes a small series of shales and quartzites with a thickness of about 60 to 100 feet, the shales passing upwards into those included in the lowest beds of the Dolomite. These shales when unweathered are usually thinly laminated, dark blue to black in colour, and frequently very hard, flinty, or cherty in character. Interbedded with the shales at various horizons, but perhaps more frequently near the conglomerates at the base of the series, there occur beds of dark bluish grey quartzites from 1 to 3 feet in thickness, which usually crop out at the surface.

At the outcrop the rocks of the Black Reef show considerable weathering, and consist of hard reddish-brown sandstone, with yellow and brown ferruginous shales.

(*b*) *The Dolomite.*

The general distribution of the Dolomite, the middle member of the Transvaal System, and the character of the country to which it gives rise have already been dealt with. The main characters of the formation in the Potchefstroom District closely resemble those already well known in other parts of the Transvaal, and as these have been frequently described at length in previous reports of the Geological Survey and in papers by various authors, attention will be confined in the present Report to such points as appear to be either specially well seen in the sections met with, or to be of importance in the local geology.

Owing to the difficulty of obtaining any continuous section and to the unreliability of surface dips in the formation, the estimation of the thickness of the Dolomite, except when it enters into the formation of such an escarpment as that of the Drakensberg in the Eastern Transvaal, is always a matter of considerable difficulty, and the Potchefstroom District is no exception to the rule. A comparison of a large number of sections and the study of the dips given by the beds immediately underlying and overlying the Dolomite give as a result an average thickness of 5,500 feet, which may probably be taken as approximating fairly closely to the true thickness.

In the southern limb of the Potchefstroom syncline the outcrop of the Dolomite has a fairly constant width of about 1¼ miles. It is exceptionally broad on Bronkhorstfontein (30) and the adjoining farms where, owing to repetition by faulting, it covers a width of nearly three miles, while near the point where it is crossed by the Potchefstroom–Venterskroon road the outcrop of the Dolomite narrows to less than a quarter of a mile, in sympathy with the narrowing of the outcrop of the lower portion of the Pretoria Series, apparently as a result of the pressures to which the whole of the sedimentary rocks have been subjected, having been locally accentuated by the presence of the unyielding mass formed by the igneous intrusion on Roodekraal. It will be noticed that north of this point the dip of the Dolomite, like that of all the underlying formations, is an inverted one south-eastwards towards the Vredefort granite, while to the south of the same point a normal dip towards the north-west prevails.

The zone of Dolomite lying westwards of Potchefstroom and forming part of the northern limb of the syncline is very much broader than that just considered, owing to the prevalence of much lower dips, which are frequently below 15 degrees, and sometimes as low as 5 degrees, while in a few places horizontal bedding is met with, as, for example, in the broad area of Dolomite about Witstinkhoutboom (146), south-west of Boskop. The distribution of the Dolomite to the north and west of Potchefstroom is much complicated by the occurrence of the small syncline of which Spitzkop is the centre, and more particularly the sharper anticlinal fold which brings in a long tongue of Dolomite to the west of the town. The faulting is particularly complicated to the north of the cantonments, especially near the military pumping station, and also near the railway line four miles south-west of Potchefstroom, resulting in the occurrence of several small isolated areas of Dolomite surrounded by rocks of the Pretoria Series, in dealing with which further reference to the faulting will be made.

With regard to the nature of the strata included in the Dolomite, the bulk of the formation consists of the well-known dolomitic limestone, or " Oliphants Klip." The cherty bands which occur throughout the formation attain a very conspicuous development in its upper portions, and frequently give rise to several

parallel outcrops, forming small ridges standing from 20 to 50 feet above the general level, and running parallel to the ridges formed by the lowest quartzites of the Pretoria Series. This is, perhaps, especially noticeable in the area extending westwards from the Vaal at Lindequee, although the cherty beds in the upper portion of the Dolomite are conspicuous throughout its occurrence in the district. On Kluitfontein, about six miles north-west of Lindequee, the uppermost 650 feet of the Dolomite, which is here practically vertical, include 400 feet consisting almost entirely of chert, which appears at the surface in four well-defined outcrops, ranging from 16 to 250 feet in thickness, the latter being seen in a very massive chert ridge which forms the uppermost portion of the formation, having as its topmost bed the chert conglomerate, referred to later, which has been taken as representing the lowest bed of the Pretoria Series. Some of the individual beds shown in this ridge are exceptionally massive, one in particular showing 15 feet of massive chert unbroken by bedding planes. Owing to the resistant character of these massive cherts, the horizon at which they lie is characterised by the occurrence of numerous extensive caverns, the cherty beds preventing the falling in or crushing together of the formation, after the solution of the more calcareous beds, and also rendering the entrances to such caverns more easy of discovery and entrance.

Such caverns occur on the farms Eigenaarsfontein (596), Kluitfontein (462), Modderfontein (403), and Zeekoefontein (21), all in the neighbourhood of Lindequee. The cavern on Eigenaarsfontein is very characteristic. It is situated at the base of a small kopje of chert about one mile N.N.W. of the south-east corner of the farm. The entrance, an obscure opening scarcely 2 feet in diameter, opens almost vertically into a fissure between chert walls, leading downwards at a very steep angle, necessitating the use of a rope in places. The general slope of the descent is towards the north, and the main fissures run east and west between flat or curved walls of rough chert, often much brecciated, originally interbedded with thin beds of limestone, 4 to 6 inches in thickness, which have been almost entirely removed by solution. From the descending fissure several chambers of considerable size open laterally. A descent was made to about 100 feet below the surface, beyond which the passages, partially filled with bat guano, become too small to be easily followed. Considerable quantities of water, which had entered the cave during the rain of the previous night, had all disappeared beyond the lowest level visited. Near the entrance to the cave the subsidence of the surface has given rise to a considerable pit.

The cavern on Kluitfontein is situated in the same zone of chert with thin limestone bands. In this case the entrance is a wide shaft-like opening with vertical or overhanging sides, and 25 feet in depth, from which opens a spacious cavern, 70 feet in diameter and 20 feet in height in the centre, with a rudely domed roof. There is a level floor formed by a deposit of bat guano, said to be 40 feet in depth, which is used by the local farmers for agricultural purposes.

The most interesting of the caverns in this locality is that situated about one and a half miles north of Lindequee's Drift, on the farm Zeekoefontein (21), and half a mile north of the house of Mr. Plessis, by whose courtesy the writer was able to make an examination of it. As in the two examples already described, the cavern occurs in Dolomite, with strong bands of chert. In this case, however, the bedding, instead of being vertical, has usually a low dip of from 10 to 15 degrees. The entrance, an almost circular opening about 10 feet in depth, with vertical sides, opens laterally into a dimly lighted but spacious chamber about 100 feet in width and 20 feet in height, with a floor sloping at about 20 degrees. This chamber contains the usual remains of Kaffir occupation, including, besides fragments of baskets, skins, and bones, a number of circular enclosures of the usual dimensions of Kaffir huts, with mud floors and walls 3 or 4 feet in height. The enclosures represent huts, the necessity for a roof being obviated by their situation in a cavern. A somewhat weird aspect is given to the surroundings by a number of mummified carcases of baboons, who appear to have been later occupants. The cavern can be followed without difficulty to a depth of 40 feet from the surface, and most probably extends to the level of the water in the spring, which issues from the Dolomite near the entrance. The local Kaffirs state that water was formerly to be obtained in the cavern.

The Dolomite caverns are especially interesting on account of their connection with the behaviour of the surface and underground waters in Dolomite areas, and their obvious connection with the local subsidences of the surface frequently met with. A very striking example of such subsidence occurs on Modderfontein (403), near to the middle point of the northern boundary of the farm. It consists of a hollow, about 150 yards in length and 50 yards in width, with a depth of about 30 feet, and with steeply inclined or overhanging sides. There is no alteration of the surrounding surface, so that the presence of the hollow cannot be detected at a distance. A small spring, said to be permanent, rises near one end of the depression, the water of which after flowing a few yards disappears. At the deeper end of the subsidence there are a number of vertical fissures and small caves in the chert. Although there is no obvious entrance, the extent of the surface subsidence points to the existence of a considerable cavern in the vicinity.

A similar origin must be attributed to the still more extensive depressions occasionally met with in Dolomite areas, an example of which occurs just west of the Ventersdorp road, about nine miles north-west of Potchefstroom. The depression lies in the centre of the farm Welgegund (84), and is crossed by a small road leading from Witkoppies (181) to Kromdraai (491). It is about a quarter of a mile in diameter and 20 feet below the general level, resembling a pan in general form. Although, however, a considerable quantity of water is brought into it by the drainage along the road which crosses it, there is no tendency to form a swamp, and even after heavy rain there is no accumulation of surface water, which disappears rapidly into the Dolomite below.

A similar rapid absorption of surface waters is very characteristic of the whole of those areas occupied by the Dolomite. Although usually forming a portion of the low-lying parts of the district, such areas are rarely traversed by well-defined and continuous valleys and spruits, and are without the numerous channels of surface drainage common on other geological formations. Where a definite channel does exist, as, for example, the Kromdraai and Koekemoer Spruits from Rietkuil (537) down to the Vaal River on Buffelsfontein, the channel carries no running stream, except shortly after rain. A striking exception is the Mooi River above Potchefstroom, which carries a large volume of water for a considerable distance over Dolomite. The existence of considerable bodies of water in the Dolomite is, however, shown by the frequent occurrence of exceptionally strong springs where the elevation of the surface is sufficiently low, such springs, spruits, and rivers usually rising either close to or but a short distance from the banks of the main spruits and rivers. Among such may be mentioned the springs on Buffelsvlei (87), near Boskop, and on Oudedorp (25) and Witstinkhoutboom (146), discharging into the Mooi River; that on Hartebeestfontein (573) discharging into the Koekemoer Spruit, and on Bronkhorstfontein (30) near Lindequee. In the two last-mentioned cases the water disappears before reaching the Vaal, into which it probably finds its way below the surface, together with other waters from the Dolomite area.

(*c*) *The Pretoria Series.*

The Pretoria Series is the predominating formation in this district, occupying a belt of country with a width of from fifteen to twenty miles, extending from the Vaal River in a north-westerly direction. Broadly speaking, the formation is disposed in the form of a broad synclinal fold, whose axis corresponds approximately with the wide valley traversed by the Loop Spruit and the lower course of the Mooi River. The simplicity of the main synclinal arrangement is, however, very much complicated by the occurrence of very numerous minor synclines, anticlines, folds, and faults, referred to in more detail later, which are especially numerous along the south-eastern margin of the main syncline, and lead to the frequent repetition of the beds of the Pretoria Series, as will be at once evident from a glance at the behaviour of the quartzites shown on the map.

The order of succession and approximate thickness of the various members of the series are shown in the following table in descending order :—

Pretoria Series.—(Potchefstroom District.)

		Approximate thickness.
Quartzite (Magaliesberg)		800 feet.
Shales and Diabases		7,500 „
Quartzite (Daspoort)		120 „
Shales	200 feet	
Amygdaloidal Diabase	1,700 „	3,200 „
Shales and Diabases	1,300 „	
Quartzite (Timeball Hill)		80 „
Shales and thin Sandstones (with chert conglomerate at base 20 feet)		1,000 „
Total		12,700 feet.

In the general character of the beds and in their order of succession there is a close resemblance between the Pretoria Series as developed in the Potchefstroom District and in the neighbourhood of Pretoria, the differences consisting in minor details. The three horizons distinguished by the occurrence of the Timeball Hill, Daspoort, and Magaliesberg Quartzites are well developed, and the amygdaloidal diabase usually found below the middle quartzite is also well developed, and forms a prominent feature in the geology of the district.

In the following description reference will chiefly be made to local characters, commencing with the lowest beds. *A well marked conglomerate* is almost everywhere present at the base of the Pretoria Series. It includes one or more beds, with an aggregate thickness of about 20 feet, and consists almost entirely of pebbles

and boulders of chert, from the uppermost beds of the Dolomite. A fair proportion of the boulders are usually well rounded and smoothed, but the remainder of the chert fragments are angular or sub-angular in shape, giving the whole bed the character and appearance of a breccia. The occurrence of well-rounded boulders in the conglomerate, and its persistence over very considerable areas, undoubtedly point to a small degree of denudation of the Dolomite prior to the deposition of the Pretoria Series, as suggested by Dr. F. H. Hatch.* Breccias, probably in most cases entirely due to the breaking up of chert beds by movement subsequent to their formation, are very common in the Dolomite, and should not be confused with the conglomerate just referred to as lying at the base of the Pretoria Series. The latter can in most cases be distinguished even in limited outcrops by the occurrence of a somewhat scanty, coarse, sandy matrix, usually yellowish in colour, which lies between the chert fragments, and also by its being usually succeeded by beds among which quartzites of a cherty nature alternate with the more normal types of the Pretoria Series.

The basal conglomerate is everywhere almost immediately succeeded by a series of beds, consisting mostly of shales with occasional beds of sandstone or quartzite, the thickness of the whole amounting to about 1,000 feet. This series usually forms a depression between the ridges formed by the hard cherts at the top of the Dolomite and the lowest quartzite of the Pretoria Series. The shales when seen are usually thinly laminated, sometimes dark brown in colour, and very ferruginous, but more often, especially when weathered, light grey and pink or white. Occasional beds, dark in colour, are extremely hard and flinty, and both these and the thin quartzites interbedded with them closely resemble certain bands and beds in the cherts below the conglomerate, the tendency to a cherty character diminishing upwards in the section, both quartzites and shales assuming more and more the appearance normal to the Pretoria Series. These beds are particularly well seen at Lindequee, where they cross the Vaal River about one mile east of the pont, where, however, the exposure, owing to much faulting and repetition, does not otherwise afford a representative section.

The lowest well-marked quartzite in the Pretoria Series occurs above the series of shales just described. It corresponds to the Timeball Hill Quartzites of the Pretoria section, but is not so much interbedded with shales as is the case near the Capital. It always shows a main body of thick bedded and massive quartzite, uninterrupted by shales, about 80 feet in thickness, with a number of smaller quartzites interbedded with shales or shaly sandstones, both above and below. The main quartzite is rather coarse in texture, reddish white in colour, and usually conspicuously marked with reddish bands, often showing current-bedding. The joint planes are generally coated with iron oxides, and exposed surfaces weather into deep pits separated by a network of ridges. The beds which succeed the main quartzite, like those above the Timeball Hill Quartzites near Pretoria, are usually very ferruginous in character, the shales giving rise to a belt of very red soil, from which one or two beds of highly ferruginous dark brown quartzite crop out.

The first or Timeball Hill Quartzite is succeeded by a series of shales and intrusive diabases, about 500 feet in thickness, entirely similar in character to those so characteristic of the Pretoria Series in other districts, and these in turn are overlain by an enormous sheet of amygdaloidal diabase, which corresponds closely in position, appearance, and general characters with the amygdaloid occurring about Pretoria. This extensive sheet, which occurs throughout the district at this horizon, forms the hills which lie around Spitzkop, including the conspicuous mass of Vaalkop. The sheet is about 1,700 feet in thickness, and gives evidence of being of a contemporaneous nature. Above the diabase lies a series of shales, which immediately underlie the second or Daspoort Quartzite. These shales occur very consistently at this horizon, and show a very uniform section, well seen about the base of Spitzkop, west of Potchefstroom, and at Paardekop, about two miles east of Boskop Station. At the base is a thickness of some 50 feet of hard dark brown highly ferruginous shales, succeeded by 100 feet of softer shales weathering to a light yellow colour, and overlain in turn by 50 feet of hard yellowish shales interbedded with thin sandstones and quartzites which, becoming more dominant towards the top of the series, give place to the thick beds of the middle or Daspoort Quartzite (see Section, Plate VIII).

The middle or Daspoort Quartzite forms the capping of Spitzkop and of Paardekop, and forms most of the ridges which lie on either side of the broad valley in which Potchefstroom stands. It is not so much associated with ferruginous elements as is the lowest quartzite, and consequently has less tendency to a reddish colouration, being usually light yellow in colour and very similar to the ordiary type of Pretoria quartzite, nor does it tend to weather into the pits and troughs frequently found on the lower quartzite. The thickness of the main body of the quartzite is about 120 feet, but there are also many beds of quartzite interbedded among the shales, both above and below. Between the Daspoort Quartzite and the upper or Magaliesberg Quartzite there is a succession of shales with numerous thick sheets of intrusive diabase. These occupy the upper portion of the valley of Loop Spruit around the base of the Losberg, where they are disposed in a basin-like fold below the mountain, and also a considerable area of the Mooi River Valley around Potchefstroom.

* Trans. Geol. Soc. S.A., vol. vi (1903), p. 51.

In the latter locality the series is for the most part hidden under the surface deposits, outcrops, especially of shales, being extremely rare, and in the former also the series is not well seen; so that it is difficult to obtain reliable data for an estimation of its thickness. From the data available, however, the thickness of the shales and diabases between the middle and upper quartzites appears to be approximately 7,500 feet. The sedimentary portion of the series consists almost entirely of shales, with occasional beds of more quartzitic character, whose outcrops at the surface usually die out in the course of half a mile or less.

The upper or Magaliesberg Quartzite, the uppermost of the three quartzite zones, attains a very much greater development than either of the two already described, having a thickness of about 800 feet.

It occupies, however, only a very small extent of the surface, being well represented only in two localities, where its horizontal or slightly synclinal disposition has enabled it to successfully withstand the prolonged denudation to which the district has been subjected. These two localities are the Losberg and the northern portion of Plessieskraal (529), about four miles due south of Potchefstroom. The quartzites are very hard and white or pale pink, cream, or yellow in colour, with bedding planes either unusually smooth or showing very sharply defined ripple-marking.

The bulk of both the Groot and Klein Losbergen is composed of this quartzite, which forms the flat top of both portions of the Berg, a sheet of intrusive diabase, which breaks the continuity of the quartzites, giving rise to a terrace-like feature on the mountain.

On Plessieskraal the quartzites also give rise to a broad and elevated plateau, which, however, does not form so dominant a feature in the topography of the district as the Losberg. The quartzites, which over the greater portion of the plateau are nearly horizontal, are sharply faulted into a vertical position on its south-eastern edge.

Pretoria Series.—Structure.—It has already been noticed in dealing with the general structure of the area that the Pretoria Series participates in the broad synclinal arrangement prevailing in the Potchefstroom District. Compared, however, with the other formations there present, the series exhibits considerable complexity of detail, due to extensive and complicated folding under the influence of those disturbing forces already referred to, whose effects are so strikingly displayed in the complete inversion of the Witwatersrand and Ventersdorp Systems, and of the Black Reef and Dolomite around the Vredefort Granite mass. While these more massive members have been affected more or less uniformly and as a whole, the Pretoria Series, owing most probably to the predominance of shales in the formation, and to the lesser burden of super-incumbent material, has been broken up into a great number of minor folds, frequently of a very complicated character, as for instance on the eastern portion of Elandsheuvel (587), about five miles east of Potchefstroom. In the following paragraphs reference will be made to such minor structural features as appear worthy of special remark.

A glance at the map will show that the Dolomite along the southern margin of the main syncline of the Pretoria Series forms one continuous zone, and is not broken up into minor areas; and this is also true of the Pretoria Series up to the lowest quartzite, if perhaps we except a repetition on Rooipoortje (278). Very different conditions, however, prevail in beds a little higher in the Pretoria Series, including the second or Daspoort Quartzite, and the amygdaloidal diabase below it. It is this portion of the series which has been thrown into the numerous minor synclines and anticlines shown in the belt of country lying between the Dolomite and the valley of the Loop Spruit, and lower part of the Mooi River, resulting in the frequent repetition of the second quartzite. Particularly noticeable are the curved ranges of hills formed by the quartzites about Enzelpoort (601), Syferfontein (154), and the eastern part of Elandsheuvel (589), where the structure is particularly broken and complicated; the repetition of the quartzites along the south-eastern boundary of the farm greatly increasing their apparent thickness.

Great contrasts exist in the magnitude of the surface features formed by the outcrops of the same series of quartzites, which in one place may give rise to conspicuous ridges rising 300 or 400 feet above the general level, while elsewhere it may scarcely rise above the grass. These differences are in most cases directly connected with the dip of the beds, and as a general rule it may be said that the prominence of the feature formed by the quartzites is inversely proportional to the amount of dip. When the dip is very low, from about five to ten degrees, broad and conspicuous ridges or sloping plateaux are formed, as on the western portion of Hartebeestfontein (584) to the east of Potchefstroom, and again in the northern portion of the syncline in the broad mass of Paardekop, west of Boskop Station. The same conditions are shown in Spitzkop, west of Potchefstroom, and in the case of the uppermost Pretoria Quartzites in the Losberg, and in the elevated plateau on Plessieskraal (529) already referred to. On the other hand, where the quartzites are vertical or nearly so, they may form an outcrop rising only a few feet above the surface, and indistinguishable from the general level when viewed from a short distance. This is very noticeable in the quartzite outcrop which runs across

the southern portions of Eigenaarsfontein (596) and Rietfontein (114). It may be noted that along the southern margins of this main syncline, the second or Daspoort Quartzite forms in general two more or less continuous outcrops, between which lie the more broken outcrops of the minor folds. This interval varies very much in width, being very wide where it includes the minor syncline of Enzelspoort and Hartebeestfontein, and very narrow where it shares the constriction shown by the outcrop of other strata about the southern portion of Plessieskraal, due south of Potchefstroom. The very broken condition of all the sedimentary rocks about Plessieskraal (529) and Roodekraal (678) appears to be largely due to the extensive igneous intrusion which occurs there, and to be a result not so much of the original intrusion of the rock, as of its presence as a strongly resistant mass during the action of subsequent pressures. The effect on the dip of the adjoining sedimentary rock is strikingly shown by the quartzites and shales which strike against the igneous mass from the north, about the centre of Roodekraal, the dip continually rising as the mass is approached, resulting finally in a complete inversion. On the north-west side of the same intrusion, the quartzite ridges crossed by the Venterskroon road also show a high degree of faulting and disturbance due probably to the same causes.

The upper portion of the Pretoria Series from the Daspoort to the Magaliesberg Quartzite occupies a considerable area in and about the Losberg, around which the outcrops of the various beds are disposed in a roughly concentric fashion, occupying the central portion of the main syncline. Judging from the shale and diabase outcrops seen in the more elevated ground on the fork of the Mooi River and Loop Spruit immediately east of Potchefstroom, it appears probable that a somewhat similar, but more broken and irregular, synclinal arrangement obtains to the south of the town, under the extensive covering of drift and alluvium which hides the solid geology in that area. In this case the common centre of the outcrops would be the quartzite plateau on Plessieskraal (529). Owing, however, to the very broken character of the geological structure shown on three sides of this area, and the almost entire absence of outcrops over a width of some six miles or more, it is not possible to arrive at a very positive conclusion respecting this area.

Along the edge of the northern limb of the main Potchefstroom syncline there is in general not so much complicated folding as that described in the south. To the north-east of Potchefstroom the structure is simple, the Pretoria Series dipping more or less uniformly at low angles towards the south-east, the Daspoort Quartzite forming the escarpments seen to the east of the railway when nearing the town. Equally simple is the structure of the minor syncline of which Spitzkop occupies the centre, and of the escarpment along its western edge, by which the Gatsrand, after an interruption near Boskop Station, is continued south-westward through Machavie Station towards the Vaal.

Along a line running S.S.W. from Boskop Station and passing about two miles west of Potchefstroom, however, much severe faulting occurs, associated with overfolding, giving rise to very broken conditions which are especially noticeable to the north of the cantonments, and also north of the railway line, four miles south-west of Potchefstroom town. The extensive tongue of Dolomite to the west of Potchefstroom represents the denuded axis of a sharp somewhat overfolded anticline passing southwards, about the point where it crosses the railway line, into a number of faults, whose general effect is that of an overthrust, which appears to account to some extent for the complicated outcrops of the quartzites in the broken area south of the line. Immediately north of the cantonments, about the military cemetery, a small faulted anticline brings the lowest Pretoria quartzites and the associated shales to the surface between two areas of Dolomite. At the pumping station a little further north there is also much local disturbance by which the outcrop of the lowest quartzites and shales of the Pretoria Series is considerably displaced, and small faulted outcrops of Dolomite brought to the surface on the east bank of the Mooi River, about one-quarter of a mile north of the pumping station. The water-furrow, from which the cantonments supply is taken, passes just above the pumps, through an outcrop of very coarse conglomerate, containing numerous boulders of quartzite up to 6 or 8 inches in diameter and differing considerably from the usual appearance of the conglomerate at the base of the Pretoria Series, of which, however, it is probably a local development. The only other explanation would be to refer the conglomerate to the boulder beds of the Ventersdorp System, with the description of which it agrees in some respects, and the fact that it here apparently underlies the Dolomite, and is itself underlain by an amygdaloidal diabase further strengthens the suggestion when examined as an isolated occurrence. Both the latter conditions, however, are the result of the inversion of the formation which prevails for some distance along this line of outcrop at the base of the Pretoria Series. Just west of Boskop Station there is a considerable degree of local faulting, probably related to the folding which occurs to the north-east beyond the limits of the present map, and which breaks the continuity of the Gatsrand.

(d) Igneous Rocks.

Associated with the Transvaal System and particularly with the Pretoria Series, igneous rocks, mainly intrusive diabase sheets, play a conspicuous part in the geology of the Potchefstroom District and occupy a

very large proportion of the surface about the town of Potchefstroom and in the zone occupied by the Pretoria Series, extending north-eastwards and south-westwards from the town.

Diabases.—These rocks are for the most part intrusive sheets, very similar in character to those already frequently described in connection with the Pretoria Series in other parts of the Transvaal, and calling for no special description. It may be noticed that the sheet which lies above the second well-marked quartzite of the Pretoria Series is usually to be distinguished by its more massive and coarse-grained character as compared with the average type, and by usually presenting a mottled or slightly pitted appearance on weathered surfaces.

Differing in character from the intrusive sheets is an amygdaloidal diabase of great thickness, which occupies an horizon immediately below the shales which underlie the second quartzite. This amygdaloid has several very extensive outcrops, including an area of 30 square miles or more north of Potchefstroom; and to the south of Paardekop another of similar extent, west of Potchefstroom and surrounding Spitzkop, and again on Hartebeestfontein (584), Witpoort (586) and the neighbouring farms, to the east of the town. Broad belts of the same rock cross the Vaal near Scandinavian Drift, and to the east of the mouth of Koekemoer Spruit. The amygdaloid is a fine-grained, hard, greenish-grey rock usually distinguished by the presence of numerous amygdales. These are generally somewhat widely separated, and sometimes very few in number, or absent altogether. The amygdales usually consist of finely crystalline translucent quartz with a marginal portion consisting of non-crystalline silica. The smaller amygdales are frequently composed of chloritic minerals. In thin sections the rock is seen to be much decomposed by the ferro-magnesian constituent being almost entirely changed into secondary chloritic products, showing deep blue interference colours. The shape of the crystals, together with the traces of a fibrous structure and irregular transverse cracks, suggests enstatite as the original ferro-magnesian mineral. The felspars, also much altered, occur as small lath shaped crystals. There is evidence of considerable secondary silicification throughout the mass, a feature which accounts for the hardness of the rock. The thickness of the amygdaloid near Spitzkop, west of Potchefstroom, is about 1,700 feet. It appears to represent a contemporaneous flow similar to those which have a very widespread distribution at a corresponding horizon in the Pretoria Series in other parts of the Transvaal.*

Although probably present in considerable numbers, dykes of diabasic rocks rarely form any noticeable feature at the surface of the Transvaal System in this district. Mention may be made of a dyke occurring in the Dolomite on the northern portion of the farm Oudedorp (25) to the west of Boskop Station. The rock is a very heavy dark-grey medium-grained diabase, composed mainly of plagioclase and augite with iron ores. It forms no conspicuous outcrop, but appears occasionally at the surface in broad flat masses, emerging slightly above the soil. On account of the level character of the surface along the outcrop of the dyke in contrast to the extremely rough ground formed by the Dolomite on either side, the road running from Boskop towards the centre of Welgegund (84), keeps along the outcrop of the dyke for a distance of two miles or more, giving the impression to anyone driving along the road of crossing a very extensive intrusion in the Dolomite. The diabase, however, only extends a few yards beyond the margin of the road. The line followed by the dyke which strikes slightly south of west forms a continuation of a fault affecting the Pretoria Series just about half a mile north of Boskop Station, which in turn appears to be connected with the axis of a somewhat sharp anticline on the eastern portion of Buffelsvlei (87). The dyke can be readily traced westwards as far as the broad vlei surrounding the big spring known as Grootfontein near the western boundary of Oudedorp, the occurrence of the dyke probably accounting for the rising of the Dolomite water to the surface at this place.

Granite.—An intrusion of amphibole granite which shows affinities with the tonalites occurs on the two farms Rietfontein (555 and 664), about 20 miles east of Potchefstroom. The outcrop which is of considerable extent has a length of some three and a half miles with an average width of about half a mile. Except at one locality near the middle point of the common boundary of the two Rietfonteins, where it is in contact with a rather coarse and massive diabase which lies between the Dolomite and the Ventersdorp Amygdaloid, the granite is surrounded on all sides by the Dolomite, but no good junction of the two rocks is exposed. Reference was made to this intrusion by Molengraaff,† who describes the rock as a fine-grained amphibole granite. The rock is somewhat fine-grained, pinkish-grey in colour, with a mottled appearance due to small scattered dark green patches of amphibole. Quartz is scarcely noticeable in hand specimens. Felspar is the predominating constituent, including orthoclase and some of the more acid plagioclases. Amphibole (dark green hornblende) is fairly abundant. In some specimens a little biotite is also present. Quartz occurs in fair quantity as small interstitial grains. The rock has many features in common with the tonalites. Similar intrusions in the Dolomite have been found on the Eastern Rand.‡

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* A. L. Hall, Trans. G.S.S.A., vol. xi, 1908, p. 47.

† Molengraaff, "The Vredefort Mountain Land," Trans. Geol. Soc., S.A., vol. vi, p. 25, 1903.

‡ F. H. Hatch, Trans. Geol. Soc., S.A., vol. vii, p. 63, 1904.

Diorite.—A very extensive intrusion of igneous rock which is in part a diorite, but which is remarkable for the considerable range in composition and character which it presents, occurs on the farm Roodekraal (678) and is crossed by the Potchefstroom-Venterskroon road. The intrusion occupies an area of some 5 square miles and gives rise to a group of pronounced rocky kopjes, almost black in colour, which contrast strongly with the ridges of the Pretoria quartzites. A common phase, much in evidence near the road is a dark diabasic looking rock usually crowded with conspicuous porphyritic felspars up to one inch or more in length. The phenocrysts are tabular in form, and show either a lath-shaped or broad flat section on the surface of the rock. Thin sections show the rock to be composed mainly of plagioclase and a light green hornblende, with iron ores and a little apatite as accessory minerals.

This phase of the intrusion grades into forms in which the porphyritic felspars, though still present, are less conspicuous and abundant, the rock having a more basic appearance and showing a tendency to become vesicular or amygdaloidal. In places the amygdaloidal character becomes very marked and the rock contains numerous amygdales often branched and frequently more than one inch in longer diameter. The constituents of the rock, as in the more porphyritic portions are still mainly plagioclase and hornblende, and the structure is very diabasic in character.

It is in this phase of the rock that the copper ores occur, to which fuller reference is made in the paragraphs dealing with the economic geology of the area.

In other portions of the mass the rock becomes less basic in character, and more like an ordinary diorite, varying through a dark grey rock of medium grain, with abundant hornblende and a few fairly large porphyritic felspars in addition to those of the groundmass, to a light grey, rather fine-grained, diorite without phenocrysts, in which the felspar elements predominate, and which also shows in thin sections, beside the plagioclase, a small proportion of orthoclase and a few grains of interstitial quartz. The quartz-diorite phase of the rock, which occurs in the south-western portion of the mass, on Vogelsang (529), recalls the tonalite on Rietfontein referred to above, with which it may be connected in origin.

Syenite.—One of the most interesting igneous intrusions in the district is a dyke of elæolite-syenite which traverses nearly the whole area in an almost due north and south direction. The dyke, which has a very constant width of about 100 feet, enters the area under description near the middle of the southern boundary of the farm Varkfontein (145), passing in a direction slightly west of south over the farms Driefontein (388), Goedgedacht (128), Rietfontein (114), Rietfontein (555), Rietfontein (554), and Buffelshoek (629)—on which farm it appears to end at the small poort through which the spruit rising in the northern corner of the farm passes to join the main spruit on Buffelshoek. The dyke possibly continues still further south, but it cannot be seen to cut the quartzites of the poort.

The dyke is vertical in position and does not usually give rise to any conspicuous surface features, although its outcrop can generally be easily followed by the eye over considerable distances, and is usually marked by large scattered boulders, even when the surrounding surface is covered with superficial drift and is without other outcrops.

The rock is usually light greenish-grey in colour, fairly coarse in texture, with a porphyritic appearance due to the presence of scattered phenocrysts of felspar averaging about half an inch in length. In thin sections the rock is seen to consist of felspar, mainly plagioclase in lath-shaped sections, with occasional larger phenocrysts which appear to be anorthoclase, together with pale-greenish augite and aegirine. The latter is frequently idiomorphic, and is markedly pleochroic. The extinction angles in some cases are large, and the mineral then probably corresponds more nearly to the aegirine-augite of Weinschenk. Brown biotite is also present and a little iron ore. Many of the interstitial spaces between the felspars are occupied by a transparent, colourless, isotropic mineral of very low refractive index—elæolite, and in one section a deep blue isotropic mineral occurs which appears to be sodalite.

On Buffelshoek the rock becomes brick red in colour, a change apparently due entirely to weathering, thin sections showing the constituent minerals to be much decomposed. In a northerly direction the dyke strikes towards the well-known dyke on Wonderfontein (685) with which it is probably continuous, and the Wonderfontein dyke again appears to be more or less directly connected with the dykes of elæolite-syenite described in the previous Reports of the Geological Survey,* which, as pointed out by Mr. A. L. Hall, are connected with the Bushveld Igneous Complex. As far as it has been traced, therefore, the dyke just described, extends more or less continuously for a distance of no less than 70 miles from the parent mass.

* Annual Report of Geol. Survey for 1905, p. 76. Annual Report of Geol. Survey for 1906, p. 122.

5. The Karroo System.

The Karroo System plays a very insignificant part in the geology of the area under review, having been met with in one locality only on the farm Wildebeestpan (385), 5 miles south-west of Machavie Station, occupying an elliptical area about 1¼ miles long by ¾ of a mile wide, and representing a small outlier of the more extensive areas of Coal-measures found south of the Vaal River. The limits of this occurrence are very difficult to distinguish, as the rocks only rarely crop out at the surface and are for the most part covered with a deep red sandy soil. The only good exposure of the Karroo rocks is that seen at the junction of a smaller road with the main road from Potchefstroom to Klerksdorp, when the latter begins to descend from the higher ground to the valley of Koekemoer Spruit. Here the sandstones have been quarried for building stone. They consist of rather coarse yellowish white sandstones with gritty patches and a few scattered included pebbles of chert derived from the neighbouring Dolomite. The bed which has been quarried is very massive, being about 8 feet in thickness. The Karroo rocks here lie horizontally, while the underlying strata of the Pretoria Series dip south-eastward at from 30 to 50 degrees. The coal-measures appear to owe their preservation from the action of denuding agencies to their having been here deposited in a shallow depression on the surface of the older rocks, and they probably do not exceed 50 feet in thickness. No evidence of the presence of the Glacial Conglomerate below them was seen.

An interesting feature in connection with this isolated patch of Karroo rocks is the occurrence just north of it of two small but typical " pans " of the type so characteristic of areas either occupied by Karroo rocks or from which such rocks have comparatively recently been removed by denudation. In this case the floors of the pans are formed by one of the diabases intrusive in the Pretoria Series, and formerly covered by the Karroo sandstones.

6. Recent Deposits.

Surface deposits of comparatively recent origin, geologically speaking, are more than usually in evidence in the Potchefstroom District, and call for special reference. While such deposits are insignificant along the Vaal River valley, they are particularly extensive in the broad valley occupied by the Loop Spruit and the lower portion of the Mooi River, and in some of the tributary valleys, especially that of the Klein Loop Spruit, and are very characteristic of the area south of Potchefstroom town, including the Government farm and the settlements. In such areas the underlying geological structure is so completely masked that it has been considered advisable to indicate them in the mapping as occupied by drift and alluvium; any attempt to fill in the solid geology in any detail being more likely to be misleading than helpful to anyone using the map, especially when the broken character of the adjacent areas is considered.

In many cases a true alluvium forming a level flat composed of black soil or sandy loam, exists along the banks of the main streams, and this true alluvium frequently merges almost imperceptibly into a belt of ground almost level or sloping very slightly towards the river, varying in width from ½ to 2 miles or more on either side of the valley. This flat is covered by surface deposits usually from 2 to 8 feet in depth. The commonest type is a light brownish coloured soil, the greater portion of which consists of very fine clayey or sandy material. At intervals there are numerous washes and patches of smoothed and partially rounded water-worn fragments of rock, which without having suffered sufficient attrition to reduce them to true pebbles, bear evidence of considerable travel, and which are frequently derived from rocks not occurring in the immediate locality. Fragments of chert and hard quartzites are the most numerous types. This soil frequently lies upon 4 to 6 feet of a deposit usually known as " ironstone gravel," a variety of laterite or " ouklip," consisting of a number of more or less independent ferruginous nodules which do not form a solid mass as in the usual form of " ouklip " common in the Transvaal. This form of the " ironstone gravel " appears to rest as a rule on shales, from the weathering of which *in situ* the deposit is in part derived. In other cases the ironstone gravel is much richer in ferruginous material, and gives rise to very red surface soil resembling that usually found overlying a diabase. This form appears to occur most frequently near a shale-diabase junction.

In addition to the types just mentioned, the surface deposits include patches and belts of black soil, which at a little depth below the surface contains numerous calcareous nodules. This form is common everywhere in the Transvaal, overl ing basic igneous rocks in the more low-lying areas, and its origin in the present instance is probably in nearly all cases similar. While, as a rule, it is possible in the Transvaal to judge with considerable certainty of the nature of the underlying rocks by the character of the surface soil, this is far from being the case in the areas occupied by the deposits here referred to. The general characteristics of these deposits suggests that, while they depend to some extent on the underlying rocks, they have also to some extent been redistributed and include among their elements the remnants of an old alluvium by which they have been considerably modified. Where the deposits occur actual outcrops of rock are extremely rare, only the diabases occasionally appearing at the surface. Much of the ground is under irrigation and nearly all has been cultivated at some time or other.

7. Economic Geology.

Although it embraces a considerable area of rocks belonging to formations which in other parts of the Transvaal include occurrences of minerals of the greatest economic value, no deposits of great importance have hitherto been found in the district under review.

Gold.—Conglomerates, in some cases carrying gold, occur at several horizons in the big series of quartzites, which forms the upper portion of the Witwatersrand System about Venterskroon. Much attention was given to these reefs by prospectors some years ago and a good deal of development work was done, especially on the Rooderand reefs, but the results attained were not sufficiently encouraging to warrant a continuance of operations.

In the neighbourhood of Venterskroon, the belt of country between the Vaal River and the Ventersdorp amygdaloid is occupied by a big series of quartzites and conglomerates. usually regarded as the equivalent of the Upper Witwatersrand Beds of the Rand. These attain an approximate thickness of 12,500 feet. The upper portion of the series, comprising a thickness of some 4,500 feet, forms the more northerly of the two parallel ridges crossed in approaching Venterskroon from the north. These quartzites and conglomerates underlie the Ventersdorp Amygdaloid and are generally regarded as equivalent to the Elsburg Series. They include a large number of beds of conglomerate, more numerous towards the lower portion of the series, and locally known as the Amazon Series. The approximate horizon of these conglomerates is indicated in the general section on Plate VIII. A considerable amount of development work has been done on these conglomerates at the workings on Rooderand (26). Here the bankets alternate with rather coarse yellowish quartzites. The individual beds at the outcrop vary from thin washes of pebbles up to several feet in thickness. As a rule they have no sharply defined hanging or footwall, but merge into pebbly quartzites on either side. Occasionally, however, the beds are well defined for a few yards along the strike. The individual beds are not persistent, but continually vary in thickness laterally, thinning out and being replaced at approximately the same horizon by similar lenticular bodies. Where several beds coalesce, a very considerable thickness of conglomerate results. The pebbles in the conglomerates vary in diameter from about ¼ of an inch to 3 or 4 inches, with an average of about 1½ inches. Large and small pebbles occur together. Usually smooth and well rounded, the pebbles are occasionally very flat with somewhat angular outlines. They are composed largely of rather coarse-grained vein quartz mostly white, but frequently dark-bluish grey. Pebbles of quartzite also occur, and banded pebbles are fairly numerous. In the unweathered rock pyrites is abundant, usually in the form of coarse sharply defined crystals on the outside of the pebbles. The matrix is rather coarse and gritty, and usually very abundant, so that the pebbles are somewhat scattered. The main occurrence of conglomerates lies at an horizon corresponding to that on which stand the old mine buildings on Rooderand, but many thin conglomerates and pebble washes occur throughout the quartzites up to the junction with the overlying amygdaloid. The conglomerates which have been opened up are stated to contain in places gold to an average amount of 4 or 5 dwts. per ton.

The above series of conglomerate beds is locally known as the *Amazon Series*, and individual names have been given to many of the individual reefs, such as the Northern Leader, North Reef, Springbok, and Stink Reefs.

Besides the above well-marked conglomerates, two other series of bankets are locally distinguished.* These occur in the thick series of massive quartzites, which form the broad ridge between that which includes the Amazon Series and the Vaal River. Rous' Series includes a number of small conglomerates occurring over a thickness of about 3 feet at a horizon which crosses the road from Potchefstroom to Venterskroon at the cutting, about 1 mile north of the latter. The individual pebble beds are ill-defined, and the pebbles are small, averaging about ½ inch in diameter, and rarely exceeding 1 inch. They are not well-rounded, but sub-angular, composed mostly of white quartz, with occasional banded pebbles which weather down to fine sandy material. Comparatively little prospecting has been done on this series.

At a considerably lower horizon in the quartzites occurs the Meister's Series of reefs, which includes the Red, Jumbo, and Odin Reefs, names applied at various localities along the strike. The outcrop of the series, in the neighbourhood of Venterskroon, usually lies on the steep slopes forming the northern side of the valley of the Vaal. The reefs at this horizon, contrary to the impression given by the application of such names as "Jumbo," are extremely thin, varying from 1 to 9 inches in thickness, or represented only by a thin wash of pebbles, or a band of coarse grit. The pebbles are mostly very small and dark in colour, with occasional larger ones up to 1 inch, of a sandy character when weathered. Samples of the reef are stated to give very good assays in places, especially where the reef is from ½ to 4 inches thick.

* Stanger Higgs, Trans. Geol. Soc. S.A., vol. vi (1903), p. 32.

A little below Meister's Reef another thin reef known as the " Acme Leader " is locally recognised. It consists of a small banket 2 to 4 inches thick. The pebbles are small, glassy and brittle, and usually black in colour.

On the other side of the Vaal, in the series of quartzites forming the ridge south of the river, and regarded as occupying a horizon near the top of the Lower Witwatersrand Beds, reefs have been met with in two or three small and widely separated outcrops, known as the Veldschoen Series. The efforts made to trace this conglomerate have not been very successful, and the results obtained do not appear to have been encouraging.

Considerable interest was manifested at one time in the exploration of the various conglomerates in the neighbourhood of Venterskroon, which was followed, however, by a long period of inactivity. At the present time an effort is again being made to work the reefs on a small scale. Much prospecting work for gold has also been carried on along the conglomerates of the Black Reef Series in the district, mainly on the line of outcrop which runs through the western portion of the area, and is continued towards Klerksdorp, where the same series has been mined. In the area here dealt with, the most extensive prospecting was done on the farm Eleazar (617), but the results attained have not resulted in any subsequent mining work.

Copper.—Copper ores have long been known to occur in connection with the big igneous intrusion on Roodekraal (678), to which reference has been made in the section dealing with the igneous rocks associated with the Transvaal System.

The rock in which the copper occurs, at a point near the centre of the intrusion, is a dark green, close-grained, diabasic looking rock with occasional tabular porphyritic crystals of plagioclase, and numerous amygdales of calcite and chlorite. In thin sections the rock shows a meshwork of plagioclase with interstitial hornblende, usually much altered to secondary chloritic products. The whole rock is much decomposed and contains much secondary calcite, of which also the majority of the amygdales consist.

The rock is massive, but traversed in all directions by numerous joint planes, many of which show thin coatings of azurite and malachite. In places it contains numerous small patches or " blebs " of bornite averaging a quarter of an inch in diameter, and quite unconnected with each other or with any main body. In size, shape, and mode of distribution they correspond with the amygdales of calcite and other secondary products which occur in the country rock.

As far as the present workings show, these small lodes of bornite do not appear to be connected with any distinct lode, although they are of largest size, and more numerous on both sides of an indefinite fissure, or more pronounced joint plane, which has been followed for a few feet in the workings. The mode of occurrence is unusual and suggests an impregnation of the country rock with copper ores, which have been mainly deposited in pre-existing vesicles corresponding to the amygdales in other neighbouring portions of the intrusion. Near the surface the vesicles are empty or partially occupied by coatings of malachite and azurite.

Building Stone.—The massive sandstones which occur in a small outlier of the coal-measures on the farm Wildebeestpan (385) afford large blocks of stone for building purposes. The stone, a rather coarse white sandstone, is similar to that obtained from the same formation in many other parts of the Transvaal, and has been quarried to a small extent for local use.

Chert.—The recent introduction into the Rand gold mining industry of tube mills has created a demand for material suitable for use as a lining. Certain beds occurring about the zone of transition from the Dolomite to the shales of the Pretoria Series, consisting of a dense black chert, have been found very suitable for the purpose, and are now being worked in the neighbourhood of Machavie Station. Similar material probably occurs very generally at a corresponding horizon in many localities. The value of such occurrences will naturally depend to a large extent upon the ease with which the beds may be quarried, and their distance from the railway.

Water-Supply.—That portion of the Potchefstroom District which lies along the banks of the Vaal is fortunate in being able to draw upon one of the largest river supplies in South Africa, although this has hitherto been put to little use other than for the ordinary watering of stock. In one or two cases, however, private individuals have made use of the river supply for irrigation purposes with very good results. On the other hand, full advantage has been taken of the wonderful supply afforded by the Mooi River, whose constant flow, easily distributed over a very extensive area, attracted the earliest settlers in the Transvaal, and has given rise to one of the most important agricultural centres in the country. The peculiar characteristics of the Mooi River have already been referred to in dealing with the drainage systems. The main sources of the stream lie outside the area under review, but may be briefly referred to. Like many others of the more remarkable perennial streams of the Transvaal, the Mooi River originates in a series of strong springs issuing

from the Dolomite. Deriving the main portion of its supply from the well-known spring on Gerardminnebron, the stream is reinforced by the water from the springs on Klerkskraal and Wonderfontein. Below Frederikstad the stream is further supplemented by springs issuing from the Dolomite on the farms Buffelsvlei (87), Oudedorp (25), and Witstinkhoutboom (146), the last in particular contributing largely. From the point a little above the railway bridge at Potchefstroom, where the river ceases to flow over Dolomite, down to its junction with the Vaal, the stream receives no further additions of any magnitude or permanency except in the way of flood waters. At the same time, the absence of dolomite along its course obviates the possibility of such disappearances of the water into underground channels as occur in the upper course of the river, and are generally characteristic of streams in dolomite areas.

Reference has already been made in this connection to the valley of the stream known in its lower portion as Koekemoer Spruit. Although receiving the drainage of a very considerable area, the greater portion of that part of the valley which lies upon dolomite, extending from Rietkuil (537) to the Vaal River, carries no permanent stream. A strong spring issuing near the middle of Hartebeestfontein (573) affords a stream which supplies water to two or three homesteads and farms, whose cultivated lands are in strong contrast to the unoccupied condition of the same valley for many miles, both above this point and further down where the stream again disappears into the Dolomite. Broad low-lying valleys in the Dolomite, such as that just referred to, should offer considerable scope for artificial supplies, which should be obtainable at a comparatively short depth below the surface.

Somewhat similar conditions obtain on the Dolomite area situated near Lindeque. In this case numerous springs rise along the middle portion of the spruit draining Bronkhorstfontein (30) and serve to supply a group of farms closely adjacent to one another. There is, however, no visible discharge to the Vaal River, and the Dolomite area on the western portion of Bronkhorstfontein is entirely devoid of surface water.

The Loop Spruits, which occupy two of the largest valleys in the district and which drain very extensive areas, are remarkable for the small quantity of water which they discharge. For a considerable portion of the year they do not flow, but consist of numerous disconnected pools. The Groot Loop Spruit drains practically the whole of the country occupied by the Pretoria Series lying west of the Losberg, including the slopes north and south of the Berg. The small discharge from Loop Spruit points to a comparatively small run-off, which might also be expected from the small amount of fall shown by the country drained by the stream, and from the heavy covering of surface drift, of a semi-alluvial character, which covers a large part of the valley. Both conditions should be favourable for obtaining fair supplies of water from bore-holes of moderate depth over this area.

With the exception of the supplies mentioned above, the district is characterised by the comparative fewness of permanent springs and streams, the smaller kind of spring such as is of frequent occurrence in some districts, such as Middelburg, being rare. A few such are found rising in the heavy deposits of sand, which accumulate round the broad flanks of the Losberg from the weathering of the quartzites above. Most of the ridges formed elsewhere by the Pretoria quartzites in the district afford insufficient catchment to give rise to permanent springs. The broad slopes of the hills formed by the Ventersdorp Amygdaloid give rise to a few permanent springs which, however, are remarkable for their insignificance in comparison with the extent of their catchment areas.

III.

THE GEOLOGY OF THE HAENERTSBURG GOLD-FIELDS AND THE ADJOINING PARTS OF SECOECOENILAND EAST OF THE LULU MOUNTAINS.

By A. L. HALL (*Geologist*).

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1. Introduction.

The following report deals with the northerly continuation of field-work completed during the winter months of 1906.

During that year mapping was carried on from Lydenburg as far north as the junction of the Waterval and Spekboom Rivers west of Ohrigstad; in the present year the work was extended north-westwards as far as Malips River, so as to include practically the whole of the Haenertsburg Gold-fields and the greater portion of Secoecoeniland from the crest line of the Lulu Mountains eastwards to the Great Eastern Escarpment of the Drakensberg. The area examined forms a strip of country, roughly, 25 by 50 miles in extent, and comprises 1,366 square miles, over which 1,007 miles of boundary lines were traced.

In the eastern and northerly direction the work was carried down to below the main escarpment, in some cases to the commencement of the older granite. In the opposite direction the examination was extended to well within the norite margin of the Bushveld Plutonic Series, so that the entire succession of the Transvaal System was mapped. We, therefore, obtain for the first time a comprehensive view of the character and distribution of this system as developed in the Eastern Transvaal. It will be seen below that there are many features in regard to which it differs markedly from those shown in the better-known portions of the central parts of the Colony.

The area under review is of some importance, as it includes practically the whole of the Haenertsburg Gold-fields, about which very little accurate information was hitherto available. The margin of the Bushveld Plutonic Series also contains certain deposits of economic value, notably chromite. Lastly, there is the extensive belt of unsurveyed proclaimed Government ground east of the Oliphants River, which apparently has never yet been prospected and is practically unknown country.

2. Physical Features.

(*a*) *Topographical.*

The character and distribution of the leading topographical features shows great variety, due mainly to the many different types of rocks making up the geology of this district and to the great differences in elevation. Thus, south of Haenertsburg the escarpment of the Strydpoort Range attains a maximum height of close on 7,000 feet, while the junction of the Steelport and Oliphants Rivers is only about 1,700 feet above sea-level. It will be convenient to consider certain belts of country running roughly parallel to the strike and not sharply defined from one another, but each characterised by a distinct physiography. These are:

(i) The country from the crest line of the Lulu Berg eastwards as far as the top of the Transvaal System.
(ii) The country occupied by the Pretoria Series.
(iii) The area east and north of the Oliphants River.
(iv) The main escarpment of the Drakensberg and the Strydport Ranges.

(i) *The Bushveld Country East of the Lulu Mountains.*—The type of scenery found in this area is that of true Bushveld; the average elevation does not exceed 3,000 feet above sea-level, excepting along the Lulu Mountains. These form a striking and continuous chain of hills running approximately north and south from a little south of Malips Drift to the Steelport River, and rising to a height of some 1,500 feet above the general level of the plains. Towards the east the ridge passes with a sharp descent into the densely wooded and low-lying Bushveld. The latter contains a number of more or less isolated and somewhat elongated pyramidal kopjes (see Plate III, Fig. 1) standing out in strong contrast with the surrounding plains—e.g. Mosego, Swali, and Mulamoolah. Since the whole of this portion is made up of a single norite formation, the hilly portions consist

entirely of dark coloured rugged crests, often weathering into gigantic spheroidal blocks (see Plate IV), and carrying a peculiar flora, among which the large and conspicuous species Euphorbia candelabra is the most common and striking. Certain portions of the norite possess a composition different from that of the average rock, and this cause probably accounts for the presence of two or three very well marked ridge-like features running parallel to and on the east side of the Lulu Mountains. Looking from the neighbourhood of Malips Drift south-eastwards down the Oliphants River towards Secoecoeniland, the very perfect regularity of these subsidiary norite ridges is most striking, and reminds one of the common appearances seen associated with dip slopes and escarpments of a hard and inclined sedimentary series. On the south of the junction of the Spekboom with the Steelport River lies another prominent norite ridge—the Maronah Mountains, running parallel to the Spekboom River. The norite area east of the Lulu Berg forms the heart of Secoecoeniland, and is a very lonely and secluded bit of country full of interesting historical associations. It is, unfortunately, served by only one road—this is the old Lydenburg road—which crosses the Steelport River at Fort Burger, and runs along the foot of the eastern slopes of the Lulu Mountains; in every other direction the country is almost impassable for heavy transport. But for the very poor water-supply, it would form excellent agricultural ground.

(ii) *The Country Occupied by the Pretoria Series.*—Towards the east and north the broken Bushveld country of the norite passes gradually into the " Banken " scenery of the Pretoria Series. The most striking feature now is the presence of long, low and very regular ranges of hills due to the differential rate of erosion of certain harder rocks. On the whole, therefore, the type of country is very similar to that seen near the Capital, but the average elevation is much less, rarely exceeding 2,500 feet above sea-level, and the vegetation is distinctly denser. The three most regular and persistent features are due to the Magaliesberg, Daspoort, and Timeball Hill Quartzites, which are easily followed throughout the whole length of the area mapped. The two first-named ones are known respectively as the Tokane and Sakune Mountains; between them occur two more ridges; one lies a little east of the Tokane Mountains and is caused by a thick band of highly altered crystalline contact rocks; the other, due to volcanic tuffs, lies above the Sakune Range, and becomes specially marked as it approaches the Steelport River; from the Motse River north-westwards only three of these five features remain in evidence. In the Schlickmanns Kloof District, on the east side of the Lydenburg main road and about eight miles north-west of Fort Burger, the topography is a little more complicated owing to minor folding. Nearly the whole of the farm Schlickmanns Kloof (12) forms a fairly level elevated plateau some 2½ by 4 miles in extent and about 4,200 feet high. On the east side it is sharply defined by the escarpment of the main Magaliesberg Quartzite. On the west side the plateau rapidly falls towards the low-lying norite area, but the presence of at least two further thin quartzites gives rise to additional short ridges. The kloof, to which the farm owes its name, runs north and south, and owing to repeated gentle folds the main Magaliesberg Quartzite forms near the extreme southerly beacon a striking almost completely enclosed mountain kettle, floored entirely by this formation. On the whole, the Banken Country has a very poor water-supply, excepting in the Schlickmanns Kloof District and for the short distance, along which the Oliphants River cuts obliquely across the Pretoria Series.

The very uniform westerly dip causes the harder formations to stand out in a highly regular and characteristic manner. Nowhere else are the dip slopes so perfectly uniform as in this part of the country, especially from the Motse River north-westwards, where the quartzite ranges look like huge tilted tables. The country occupied by the Pretoria Series is even more impassable for anything but the lightest transport than that described above. There are no roads whatever, and in every direction progress is barred by the numerous ridges, so that most of this particular area has to be traversed with pack mules. Each hard bed, which has been sculptured into a continuous ridge, presents a well defined escarpment facing north-eastwards and northwards; of these the one due to the Timeball Hill Quartzite is the most prominent, since, unlike the same horizon in the Central Transvaal, it consists of one single quartzite, in places about 150 feet thick.

(iii) *The Area East and North of the Oliphants River.*—This practically coincides with the Haenertsburg Gold-fields, both surveyed and unsurveyed, and comprises nearly the whole of the Black Reef Series and the Dolomite. East of the Malips River the lower portion of the Pretoria Series is included. It is here one finds the wildest, most mountainous, and impassable country in the whole Eastern Transvaal. There is not a single road across the area, and in a few directions only can it be traversed on horseback. Since there are no bands of any thickness capable of retarding the influences of disintegration, the topography is no longer a linear one, but marked by extremely irregular and broken ground, highly dissected into deep precipitous valleys and gorges, over which progress is very slow and laborious. The scenery is everywhere magnificent, and the contrast between higher and lower ground is further brought out by the numerous drainage lines, which carry an abundant supply compared with the portions previously described.

Plate III.

Fig. 1.—**General view of Bushveld country in Secoecoeniland.**

Fig. 2.—**Escarpment of Daspoort Quartzite,** overlooking the Oliphant's River near its junction with the M'Thlapitsi.

Plate IV.

Norite Kopjes, Secoecoenliland.

The average elevation of this mountainous area is considerably higher than the region further south, the greater portion of the Dolomite and Black Reef Series rising to above 5,500 feet. Near the base of the first-named formation the surface is less broken and forms a narrow slightly shelving belt of plateau land, passing northwards and eastwards into the main escarpments of the Drakensberg and Strydpoort Ranges. Certain portions of this higher ground are very well suited for sheep farming, and efforts so far made in this direction have had promising results. From the junction of the Oliphants with the Steelport River north-westwards to the Magalokol (M'Thlapetsi) River stretches a belt of unsurveyed ground, about eight miles wide, which belongs to the Haenertsburg Gold-fields, and consists of highly mountainous country. This portion is practically unknown, with only one or two white homesteads near the Mamoutzuri and a very thin native population. It is quite impassable for any ordinary transport, and north of the Steelport River can only be traversed on foot.

The low-lying portion of the Haenertsburg Gold-fields up to a height of about 4,000 feet are well wooded; above that level the vegetation rapidly decreases and assumes a distinctive character; about 5,000 feet it becomes quite insignificant. The higher parts are also very much more healthy than those along the Oliphants and Steelport Rivers, which are notorious for the prevalence of climatic diseases between November and May. No doubt, in addition to the influence of elevation, the peculiar sheltered nature of the southern edge of the Haenertsburg Gold-fields also tends to produce unhealthy conditions. Since the Pretoria Series east of Malips Drift is considerably thinner and the average dip much greater, the quartzites stand out in fairly high ridges, separated from one another by narrow and confined valleys only one or two miles wide.

(iv) *The Great Eastern Escarpment of the Drakensberg and the Strydpoort Range.*—The most striking and persistent feature in the Eastern Transvaal is the Great Escarpment of the Drakensberg, which, like a great wall, defines the western limit of the Low Country. In the present area this powerful landmark runs from south-east to north-west, and comes to a sudden termination a few miles south-east of Haenertsburg, near the Wolkberg. At this point it is bent round towards the west, and continues along that direction to the neighbourhood of Potgietersrust, where it undergoes another very marked change in direction. The escarpment therefore faces roughly northwards; west of the Wolkberg it is known as the Strydpoort Range, though it is composed of the same formation as the Drakensberg. The latter escarpment in some respects shows a markedly different development to what it does further south at Belvedere and east of Pilgrims Rest. In the latter district the Black Reef Series has a very low dip, and consequently the topography is almost identical with that usually found in regions of horizontally bedded rocks. Hence the edge of the actual escarpment makes a sharp right angle and presents a vertical face towards the Low Country. Furthermore, the crest line is often at the same height for long distances, and not cut up into single peaks. Near the junction of the Steelport and Oliphants Rivers the character of the Drakensberg escarpment undergoes a marked change. In the first place the dip rapidly increases to about 20 degrees, with the result that there is no longer a vertical but an inclined slope facing the Low Country. Again, from the neighbourhood of Oliphantsberg the shaly sandstones near the base of the Black Reef Series rapidly pass into more shaly rocks and finally into true shales. At the foot of the Mahagoela and Mabola Mountains, therefore, one finds a great thickness of true shales conformable to and underlying the basal quartzites, which complicate the resulting surface forms and tend to soften the marked contrast between the sedimentary and igneous series. Thus one no longer finds the well-established topographical break, which always denotes the incoming of the older granite formation along the southern portion of the escarpment. The crest line itself from Oliphantsberg towards the Wolkberg is deeply cut down in several places by water-courses draining into the Low Country. Hence, instead of presenting a more or less level crest line, the Drakensberg escarpment is marked by a series of more or less striking peaks, among which the Mahagoela, the Mabola, the Mamoutzuri, and the Wolkberg are the most prominent. Viewed from the eastern or Low Country side, such points stand out as well-defined mountain tops, but from the opposite direction or from the Strydpoort Range they appear rather as mountainous ridges than isolated peaks. This result is partially accounted for by faults, which seem to run across the strike near the angle of bend between the two main ranges.

The escarpment of the Strydpoort Range faces to the north-north-west, and presents, on the whole, a less broken crest line than the Drakensberg. The highest point is the Iron Crown, 6,994 feet above sea-level, but towards the west the general elevation falls considerably. Unlike the Drakensberg, the Strydpoort Range has been cut through in two places by rivers, the Malips and Chunies Rivers, which run right across the mountainous ground and give rise to poorts. Another point of difference is noticeable in the relationship to the granitic area north of the Iron Crown; the contrast in elevation between the escarpment near this point and the general level round Haenertsburg is much less pronounced than along the Drakensberg, for the Haenertsburg District does not belong to Low Country properly called, but rather to the Middle Veld.

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The character and distribution of the leading topographical features shows great variety, due mainly to the many different types of rocks making up the geology of this district and to the great differences in elevation. Thus, south of Haenertsburg the escarpment of the Strydpoort Range attains a maximum height of close on 7,000 feet, while the junction of the Steelport and Oliphants Rivers is only about 1,700 feet above sea-level. It will be convenient to consider certain belts of country running roughly parallel to the strike and not sharply defined from one another, but each characterised by a distinct physiography. These are:

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could no longer yield by folding alone, but could only adapt themselves to the new conditions by dislocations. The latter are specially pronounced along the Drakensberg Range east of the M'Thlapitsi, between the Wolkberg and the Mahogoela Berg, and show a general parallelism directed obliquely to the strike. On this account the mountainous ground near the Wolkberg is split up into a series of more or less disconnected segments. In the Drakensberg escarpment the first effects due to these disturbances are seen a little south of the Mahogoela Berg; in this neighbourhood the lower portions of the Black Reef Series become gently folded, while the overlying members of the Transvaal System are still undisturbed; further north, between the Mahogoela and Mabola Berg, the folds become very pronounced, a considerable thickness of the quartzite is clearly overturned completely, and for some distance along the magnificent gorge between the two mountains the beds are vertical; at the same time the lower portions of the Dolomite begin to be affected, and the general anticlinal structure is seen in characteristic cigar-shaped outlines of Black Reef masses projecting into the Dolomite Series. The same features, only more marked, are associated with the area surrounding the Mamoutzuri; north of this up to the Wolkberg the folding is more evident in the Dolomite only; below that formation faults predominate. It is interesting to observe that the position of some of the striking gorges associated with the valley of the M'Thlapitsi River appear dependent on these lines of faulting.

The geological history of the district may be reconstructed somewhat as follows:—The Transvaal System, deposited more or less horizontally, must have originally extended much further north and east beyond its present limits, and previous to the intrusion of the Bushveld Plutonic Series was covered by the Waterberg or other formation of later date. The great igneous complex was intruded probably along the base of the Waterberg System, and the dimensions of the former are quite sufficient to have produced very powerful effects on the associated sedimentary rocks, for an area of at least 13,000 square miles is covered by rocks belonging to the complex. The immediate result of the intrusion was that the Transvaal System was depressed, so that all round the dip is now towards the central intrusion.* This explains, why the dip on the east side along the Drakensberg is directed towards the west, while along the north or Strydpoort Range the beds are inclinal towards the south. In reality the structure is much more complicated, partly because the shape of the laccolitic intrusion is not truly circular, but somewhat elongated from east to west, so that the change in inclination becomes locally much more sudden. At such points the beds apparently could no longer yield by folding, but became fractured and displaced, and the position and direction of the consequent dislocations were no doubt also conditioned by the nature of the floor on which the Transvaal System rested, since the former must have also given way to some extent. The fact that the faults affecting the district near the Wolkberg† run roughly parallel to the schistosity of the underlying older rocks points to a genetic connection, in as much as in consequence of the intrusion of the Bushveld Plutonic Series these older schistose rocks flooring the Transvaal System gave way to the intense pressure along planes of schistosity, which then determined the position of the faults. This view would explain the fact that such dislocations run obliquely to the strike of the Transvaal System. It is naturally to be expected that the intrusion of a mass of igneous material of such enormous proportions as the Bushveld Plutonic Series should produce very marked metamorphism in the Transvaal System, more especially in the upper or Pretoria Series. It will be shown below, that such is the case, both for the shales and quartzites of this series; the former, in particular, have along certain horizons been so intensely metamorphosed as to become thoroughly crystalline gneisses, with complete loss of almost all original characters of shales.

Apart from the area near the angle of bend in the two main ranges, the regularity of the geological structure is nowhere greatly disturbed. In the valley of the Steelport River, about 5 miles from its junction with the Oliphants River occurs a small fault, which has broken through and displaced the Timeball Hill and Daspoort Quartzites from north-east to south-west along a direction coinciding with that of the Wolkberg group of faults further north. In the Schlickmanns Kloof District the Magaliesberg Quartzite has been thrown into several gentle anticlines and synclines, so that instead of a single escarpment, that formation gives rise to a marked topographic feature in the form of an elevated plateau. In this neighbourhood also occur at least three additional quartzites between the main Magaliesberg Quartzite and the edge of the Bushveld Plutonic Series.

4. Descriptive Geology.

All the sedimentary formations present in this district belong to the Transvaal System, which is represented in its entirety; owing to the impassable nature of the escarpments and to the fact, that the area was approached from the Bushveld side, mapping could not everywhere be carried sufficiently far into the Black Reef Series to cover the base of that formation, so that the older granite area was examined along the

* See Molengraaff's "Geology of the Transvaal," p. 50, etc.

† Compare E. T. Mellor, Annual Report Geological Survey for 1906, p. 23, etc.

base of the Strydpoort Range only. The detailed stratigraphy established along the Delagoa Bay Railway as the type section of the Transvaal System for the Eastern Transvaal was found to hold good in a general way, but the Pretoria Series shows distinct differences, mainly in the nature of the three leading quartzites, the lithological characters of the beds below the Timeball Hill quartzite horizon, and in the presence of well developed micaceous and sericitic schists and gneisses—which represent metamorphosed shales. The development of the Dolomite and the Black Reef Series is very similar to that further south, except that for the first time the upper formation shows pronounced metamorphism. Of particular interest is the occurrence of true volcanic tuffs, which were first noticed a good deal further south, near Schoemans Kloof, south-east of Lydenburg, and are referred to in the Annual Report for 1905, page 53. In the present district these tuffs occupy a much greater area and their relationships are much better shown. The following sedimentary rocks occur in descending order :—

Pretoria Series.

Crystalline Contact Fels = Altered shale.
Magaliesberg Quartzite.
Cordierite Contact Fels and Micaceous Schists = Altered shales.
Staurolite and Chiastolite Slates = Altered shales.
Daspoort (Tunnel) Quartzite.
Sericitic Schists
Andalusite and Staurolite Slates } = Altered shales.
Timeball Hill (Nooitgedacht) Quartzite.
Staurolite Slates = Altered shale.
Ferruginous Slaty Quartzites.

Dolomite.

Dolomitic Limestone and Chert.
Ferruginous Slaty Quartzites.
Dolomitic Limestone and Chert.

Black Reef Series.

Quartzites and Conglomerates.
Shales.

The igneous rocks may be classified as follows :—

Sheets and Dykes intrusive in the Transvaal System.
Contemporaneous Igneous Rocks.
Norites and associated rocks of the Bushveld Plutonic Series.

(*a*) *The Black Reef Series.*

Regarding the general character of the lowermost division of the Transvaal System little need be added to the description given by Mr. Mellor in the Annual Report of the Geological Survey for 1906, page 31. The Series is made up by a thick succession of quartzites, sandy quartzites, shaly sandstones and shales. The tendency to a three-fold division owing to the prominence of the upper and lower quartzites alluded to in connection with the mapping of the district further south, near Belvedere,* becomes even more marked further north and is specially well revealed in the topography round the Wolkberg. The two main quartzites are separated by a considerable thickness of more sandy rocks, which weather more rapidly than the harder quartzite—while over the upper portion of the series the arenaceous and quartzitic types predominate, the lower beds are more argillaceous ; this change is scarcely noticeable at Belvedere and Marieps Kop, but becomes rapidly more pronounced in a northerly direction; thus at the foot of the eastern slopes of the Mahagoela and Mabola Mountains occurs a thick succession of thinly bedded, rather light coloured shales arranged in strict conformity with the usual westerly dip of the overlying arenaceous beds and some 600 feet in thickness.

A persistent feature of the Black Reef Series is the presence of conglomeratic beds, most prominent towards the base and above the shales, but also occurring at higher horizons, as on the western slopes between the Mabola and Mahagoela ; these bankets have given rise to some local prospecting, but are not of great economical importance. Unlike the upper members of the Transvaal System, igneous rocks are extremely rare

* See Annual Report for 1906, p. 82.

in the Black Reef Series. Along the new main road, which has recently been completed from the low country side of the Strydpoort Range across the New Found Out Mine into the Dolomite portion of the Haenertsburg Gold-fields, occurs a small outcrop of a light impure greenish rock, apparently associated with the shaly beds of the lower portion of the series, and showing a slight tendency to amygdaloidal structure with a very compact greenish groundmass. Possibly this rock represents an igneous type contemporaneous in character. It is interesting to note in this connection that Mr. Du Toit has recently described contemporaneous rocks interbedded in the Black Reef Series from the district between Vryburg and Mafeking.* The Black Reef Series covers the area immediately associated with and following on the west and south of the main escarpments of the Drakensberg and Strydpoort Ranges. The thickness of the entire series was estimated at 2,500 feet near Marieps Kop, and in a northerly direction this value seems to hold good, but between the Iron Crown and Chunies Poort on the west the series gets gradually thinner.

(*b*) *The Dolomite.*

The middle formation of the Transvaal System comprises a great succession of dolomite and chert, which closely resembles the rocks of the same horizon in the Central Transvaal. The thickness of this series is about 3,500 feet. Both the lower and upper limit are not well defined. Near the base there is a rapid transition from the calcareous through more sandy to the true quartzites of the upper horizon of the Black Reef Series, while at the top there always occurs a well marked intercalation of ferruginous quartzitic slates or slaty quartzites, separated from the base of the Pretoria Series by more Dolomite. The base of the Pretoria Series has been drawn at the point where the main body of ferruginous quartzites underlying the Timeball Hill Series first gives place to dolomitic rocks.

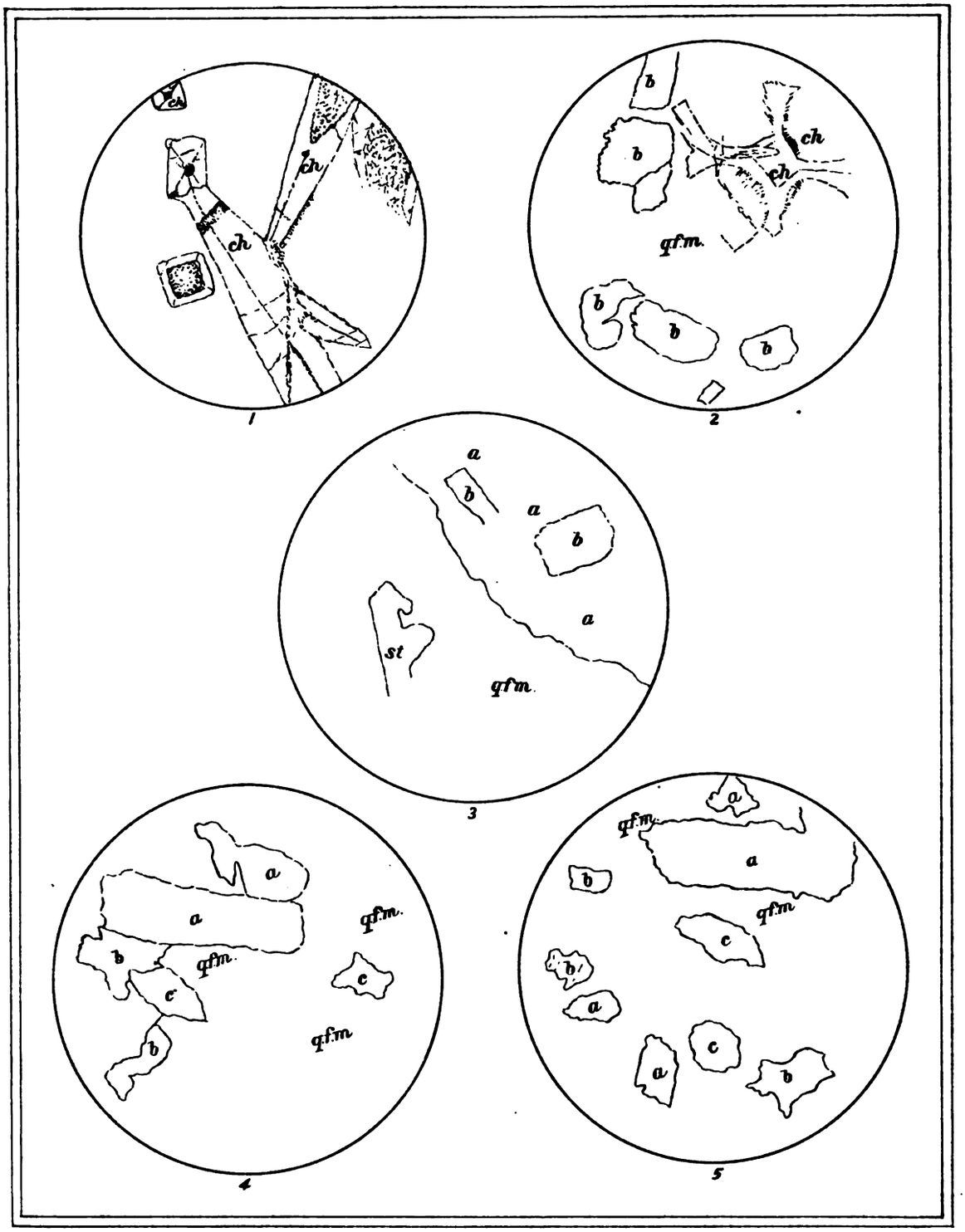
The typical country occupied by this formation always forms extremely hilly and broken ground, for it contains no beds of any thickness which differ materially from the rest as regards the rate of erosion; it is in this horizon that the disturbed nature of the system, specially near the angle between the two main ranges, becomes most marked. Powerful and complicated folding is common, particularly in the upper part of the series. The lower portion, as one approaches the plateau of the Black Reef Series tends to form a series of more or less continuous hills arranged in linear fashion and roughly concentric with the main escarpment; the view looking eastwards and south-eastwards from the neighbourhood of the old Scandinavian Camp brings this out very clearly.

The presence of an interbedded series of hard slaty quartzites seems to be a characteristic feature of the Dolomite of this district, as it also occurs near Chunies Poort and in the M'Thlapitsi Valley. The little path leading from Malips Drift to the old Scandinavian Camp shows the relationship of these slaty quartzites very clearly, where it runs along the foot of the deep and narrow valleys on Government ground (123). The beds are strictly conformable with the Dolomite above and below and about 80 feet thick, consisting of very hard thinly-bedded compact dark brownish, slaty and ferruginous quartzites, and often showing veins of blue crocodolite (locally mistaken for asbestos), averaging one-eighth of an inch in width and arranged parallel to the bedding of the slaty rocks.

Igneous rocks are not numerous in the Dolomite, when compared with the constant presence of them in the Pretoria Series. Nearly all of the former are intrusive sheets; two or three occur as dykes of no great thickness, as near the Mamoutzuri Mountain. The metamorphism of the Dolomite becomes locally well marked and produces contact rocks of some interest. The alterations are due to intrusive sheets and vary with the distance of the beds from the contact; the metamorphism is best developed in the upper portions of the Dolomite and characterised by mineralogical changes such as are commonly found when rocks rich in lime, and magnesia and containing some silica are subjected to contact metamorphism. The best localities for the study of such altered Dolomites are the following:—(*a*) Along the left bank of the Steelport River, on the farms Kromellenboog (585) and Zamenloop (586), where an intrusive sheet at the base of the Pretoria Series and a second one a little below that horizon have altered the Dolomite in contact with them; (*b*) on the farm Pendge (780), situated on the right bank of the Oliphants River, and some 16 miles in a straight line due north of Fort Burger; (*c*) on the left bank of the same river, between the Mabolaberg and the junction of the Motse with the Oliphants River; lastly (*d*) in the surveyed portion of the Haenertsburg Gold-fields, on the Government ground (No. 123 and 124), about 7 miles due south of the old Scandinavian Camp. In all these localities the horizon is the same, viz., a little below the base of the Pretoria Series.

The series of altered Dolomites form two distinct types. In one the rocks are light coloured granular limestones, in which the original bedding is practically lost, and where the presence of contact minerals is revealed under the microscope only. The second comprises darker coloured, more compact and bluish rocks,

* See Annual Report of the Geological Commission, Cape Colony, for 1905, p. 247.



qf.m. Quartz. Felspar. Mosaic.
a. Andalusite.
b. Biotite.
c. Cordierite.

st. Staurolite.
ch. Chiastolite
g. Glass
Sl. Sillimanite

m. Muscovite.
q Quartz
s. Sericite
p. Pyroxene.

pl. Plagioclase.
h. Hypersthene.

Plate V.]

Micro-Sections of Metamorphosed Rocks in the Pretoria Series of the Eastern Transvaal (Longsight and Groothoek Types).

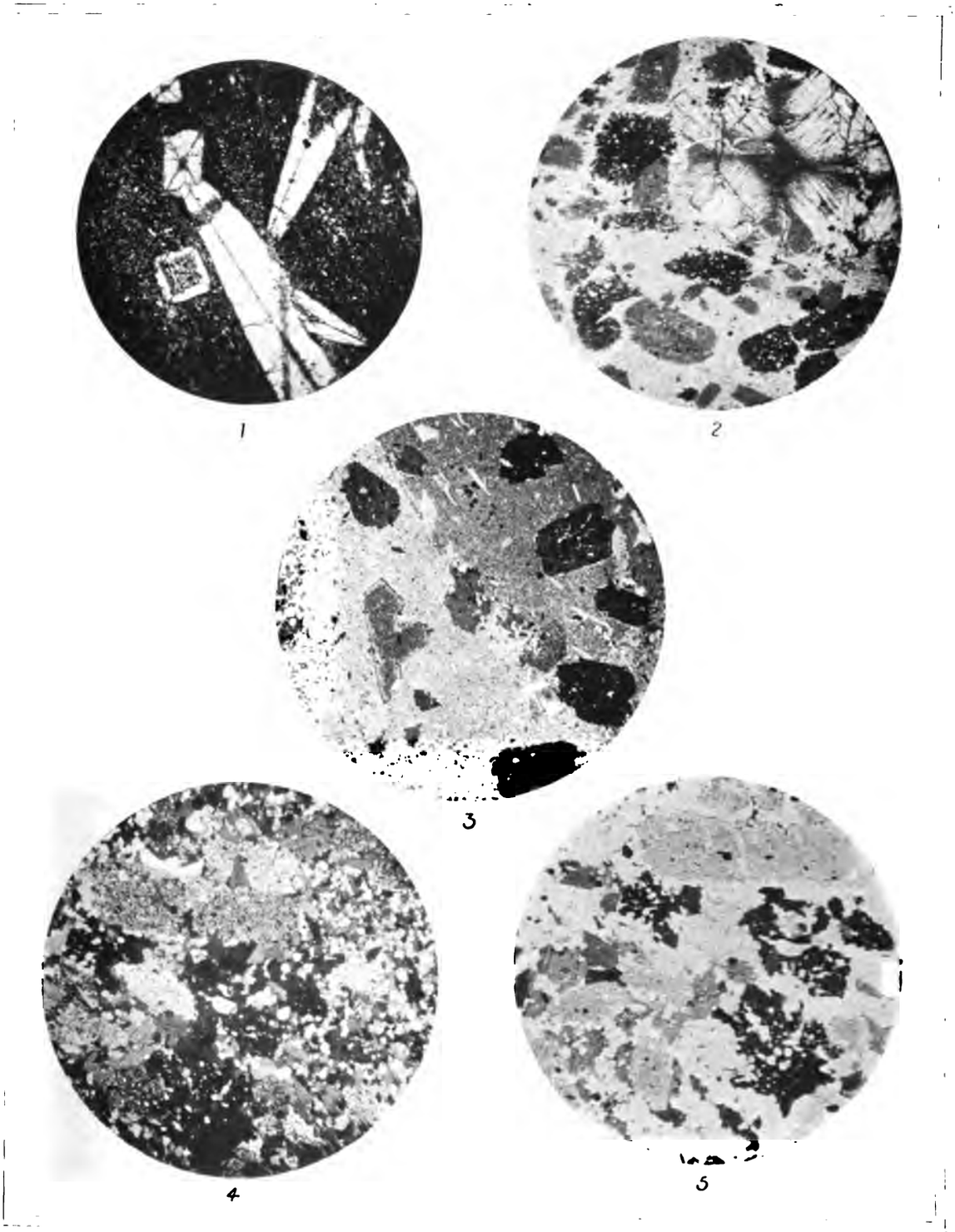
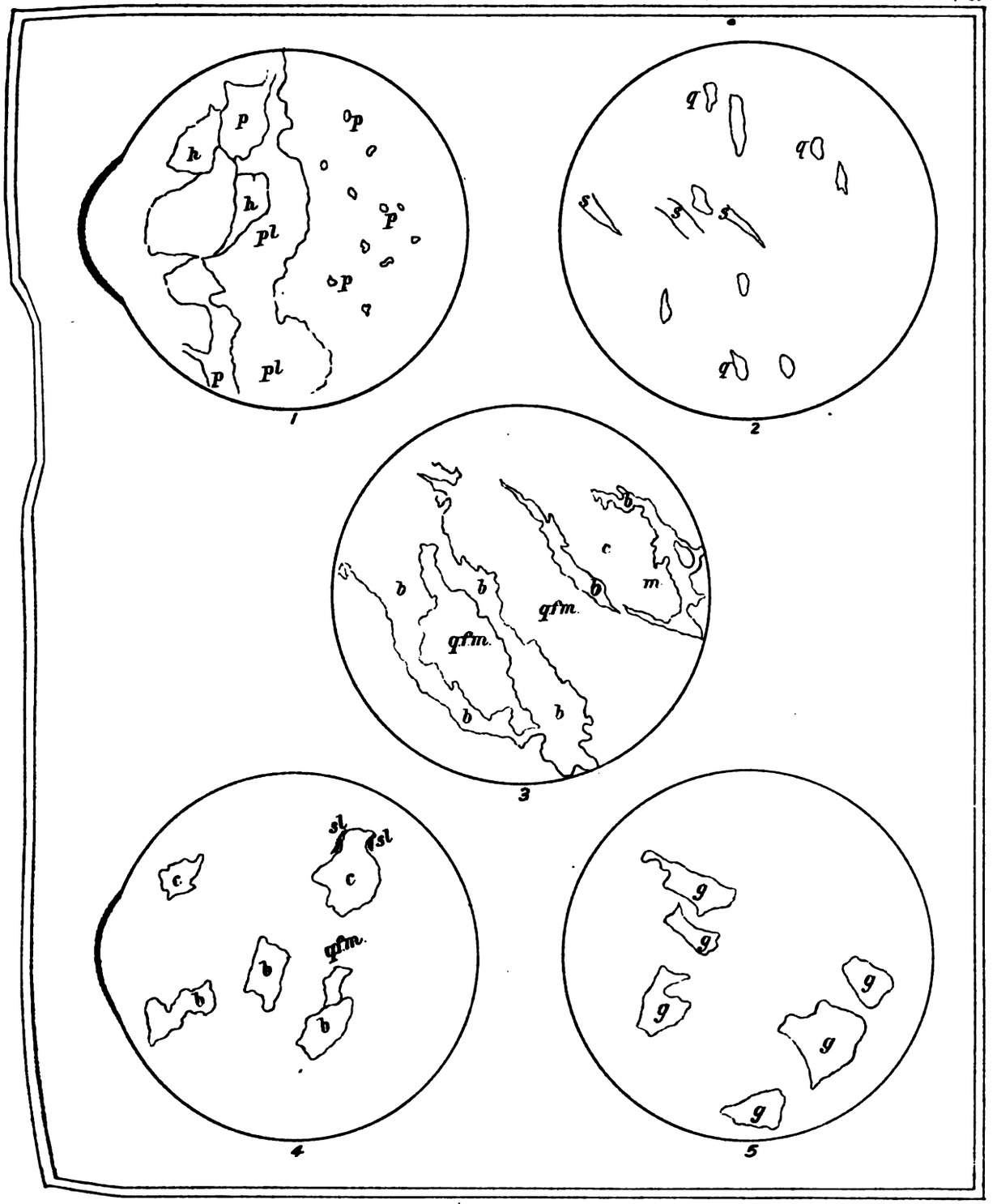


Plate I.]

Fig. 1. Chiastolite Slate × 15 diam. (*Longsight Type.*) NW. of Ohrigstad.
Fig. 2. Chiastolite Slate × 15 diam. (*Longsight Type.*) Biotite and Chiastolite. NW. of Ohrigstad.
Fig. 3. Staurolite Slate × 12 diam. (*Longsight Type.*) Idiomorphic Staurolite, next centre. Biotite. Large Andalusite, top right hand corner.
Fig. 4. Staurolite Slate. Showing ground mass completely recrystallised into a fresh quartz albite mosaic. Crossed Nicols × 20 diam.
Fig. 5. Cordierite Contact Fels. (*Groothoek Type.*) Spekboom River. Andalusite. Cordierite. Biotite. Ground mass completely recrystallised. Parallel Nicols × 20 diam.



qfm. Quartz Felspar Mosaic.
a. Andalusite.
b. Biotite.
c. Cordierite.
st. Staurolite.
ch. Chiastolite.
g. Glass
sl. Sillimanite.
m. Muscovite
q. Quartz.
s. Sericite.
p. Pyroxene.
pl. Plagioclase.
h. Hypersthene.

Plate VI.]

Micro-Sections of Metamorphosed Rocks and Volcanic Tuffs in the Pretoria Series of the Eastern Transvaal (Groethoek and Malips River Types).

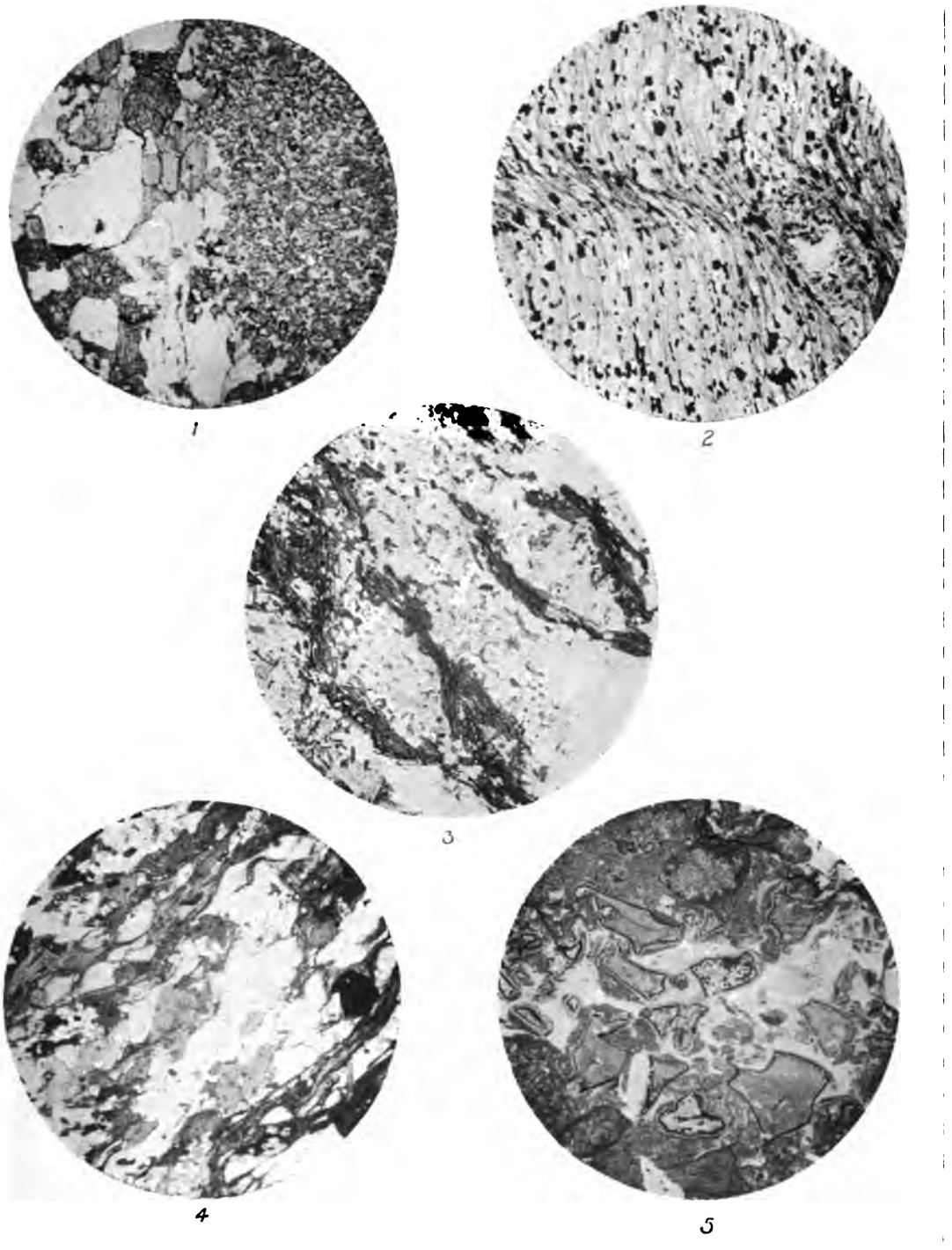


Plate II.]

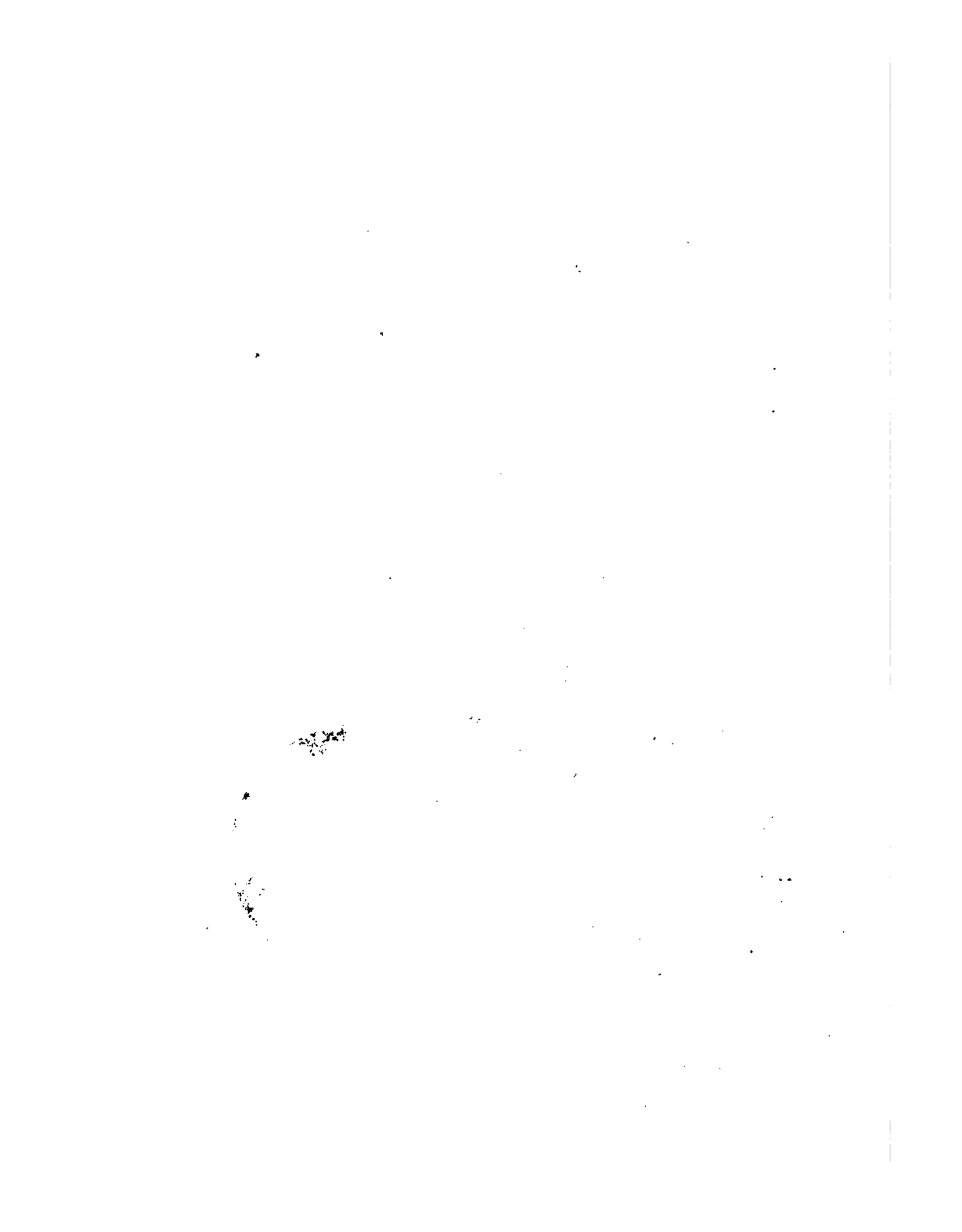
Fig. 1.—Contact between margin of Bushveld Plutonic Series (coarse part on left) and Pyroxene hornfels, altered Pretoria shale, finer grained part on right. (*Groothoek Type.*) Groothoek, N. of Fort Burger. × 15 diam.

Fig. 2.—Sheared Daspoort Quartzite × 20 diam. "Relikt" and Schistose Structures. Haenertsberg Goldfields.

Fig. 3.—Mica Schist × 15 diam. (*Sheared Longsight Type.*) Eye-structure. Completely recrystallised ground mass. Haenertsberg Goldfields.

Fig. 4.—Cordierite-Contact-Gneiss × 15 diam. Cordierite. Biotite. Sillimanite. (Paragneiss.) M'Pathlele's Location.

Fig. 5.—Volcanic Tuff, near Lydenberg. × 12 diam.



which still retain the bedded character, show certain contact minerals visible to the naked eye, and do not essentially differ in general appearance from unaltered Dolomite.

The former group becomes most marked close to the line of contact and has no great width. The best examples were found along the left bank of the Steelport River, a little below the base of the Pretoria Series; these are light coloured granular crystalline rocks, in which most of the original bedding is lost. In thin section the following minerals can be made out in order of abundance :—Spinel, calcite and wollastonite; the groundmass is markedly granular and consists essentially of quartz and calcite. Spinel occurs in numerous colourless isotropic crystals in outlines strongly indicating the regular system; the wollastonite is colourless and in irregular larger grains, which yield good biaxial figures in convergent light; these exhibit negative character.

The second type of altered Dolomite comprises dark bluish rocks, closely resembling ordinary Dolomite, always still well bedded and showing contact minerals in the hand specimen. The most prominent of these is a kind of actinolite in conspicuous needles up to half an inch long. The groundmass is made up of an intimate association of quartz and rhombohedral carbonates, but distinctly less crystalline than in the lighter coloured granular type, and sometimes containing a good deal of carbonaceous impurities. Among the constituent contact minerals one can distinguish actinolite, wollastonite, scapolite and a little biotite. The amphibole is an intensely pleochroic needle-shaped actinolite in larger masses, the individual needles being often arranged in sheet-like aggregates, the central portions of which may be pale yellowish green and surrounded by a bright green zone. Wollastonite occurs usually in small colourless, fairly fresh, irregular patches, but occasionally larger crystals are found showing a set of cleavage traces parallel to the axis of symmetry. Scapolite is present in a few large and elongated crystals full of carbonaceous matter, so that sometimes they may almost lose their transparency. The crystals extinguish straight, and when cut at right angles to the optic axis well marked idiomorphic square sections are seen, indicating the tetragonal system. Biotite is quite subordinate and seems confined to impurer parts of the rock; it generally forms small more or less rounded deep brown grains, among which those parallel to c(001) predominate.

(c) *Pretoria Series.*

The uppermost division of the Transvaal System is composed of a succession of altered shales, ferruginous slaty quartzites and normal quartzites, with a large number of intrusive sheets, and at least one horizon of contemporaneous igneous rocks. The total thickness is between 6,000 and 7,000 feet. The quartzites are confined to the same three horizons, which are characterised in the Central Transvaal by the presence of arenaceous rocks; these are the Magaliesberg, the Daspoort, and the Timeball Hill Quartzites, corresponding respectively to the Witrand, the Tunnel Quartzites, and the Nooitgedacht Quartzites of the section along the Delagoa Bay railway. Since these beds are harder and less easily eroded than the associated altered shale, they give rise to long more or less straight hills, with well marked escarpments facing north-eastwards and northwards—thus producing typical "Banken" scenery, but as the beds are much thinner, the resulting features are not nearly so pronounced as in other parts of the Transvaal. Also the occurrence of bands of hard highly altered shales and thick sheets of contemporaneous tuffs gives rise to further long hills, which weaken the topographical effect of the quartzites.

The name *Tokane Mountains* is applied to the uppermost or *Magaliesberg* Quartzite, which shows a rather abnormal development in the Schlickmanns Kloof District, north-west of Fort Burger, owing to the fact of its being thrown into several minor anticlines and synclines. In the same area occur at least three further quartzites, which overlie the main one, and are surrounded by basic rocks of the Bushveld Plutonic Complex. Probably these really belong to the main quartzite, but were split off from it by the intrusion of the great Bushveld Complex. Their presence in the latter, and their general distribution agrees with that of similar masses of quartzite, included in the norite margin of the Bushveld Plutonic Series north and north-west of the Capital. The character of the quartzites belonging to this horizon is identical with that always shown in the numerous localities in the Transvaal, where this rock has been examined, excepting that in the present portion it has shared in the pronounced metamorphism affecting nearly the whole of the Pretoria Series. An account of the altered quartzites is given below.

The middle or *Daspoort* Quartzite forms a well marked ridge, known locally as the *Sakune Mountains*, and running roughly parallel to the Tokane Range from the Steelport River to Malips Drift. It forms a single light coloured quartzite, presenting a typically developed escarpment to the north-east, the base of which is strongly emphasised by the great contrast in the mode of weathering of the rock by extensive vertical joints with that of an intrusive sheet underlying it, the latter standing out in more rounded dark coloured masses—very well shown in looking up stream from the junction of the Oliphants and Mootse Rivers in the direction

of the latter. Towards the Bushveld area, the Tokane Mountain presents an extremely regular dip slope, resembling a huge slab, when looked at from a little distance. Between the Steelport and Motse Rivers the rock clearly resembles the analagous quartzite as developed elsewhere, but north-west of the latter stream it becomes more and more altered and passes into a pale greenish sericitic quartz schist.

The lower or *Timeball Hill* Quartzite differs in several respects from those of the horizon near the Capital. Instead of consisting of a number of thin quartzite bands separated by shales, it forms a single thickly bedded quartzite. Again, unlike the occurrences in the central and south-eastern Transvaal, it is practically non-magnetic and always light coloured. Its general character resembles those of the middle and upper horizons much more closely than anywhere else, and in consequence it behaves topographically just like them, giving rise to an abrupt escarpment more marked even than that of the Tokane Mountains. It is moreover the thickest of the three quartzites.

In the southern portion of the Haenertsburg Gold-fields, east of Malips Drift, the quartzites give rise to features not usually associated with the Pretoria Series in the districts so far examined. Since the dip here —about 30 degrees—is considerably higher than further south towards the Steelport River, and the Pretoria Series as a whole reduced in thickness, the harder beds stand out in a very pronounced manner, and as the valleys in places are deep, and only half a mile wide, the quartzites resemble a series of powerful parallel walls when seen from a short distance. The view from the summit of Kodoekop, looking north, is a typical illustration; the Daspoort Quartzite in particular resembles a thick vertical dyke.

The following comparative table summarises the distinctive characters of the three arenaceous horizons compared with the type section west of Pretoria:—

	Pretoria.	Secoecoeniland.
Magaliesberg Quartzite ..	One or two massive quartzites. Approximate thickness, 700 feet. Not metamorphosed.	One massive quartzite. Approximate thickness, 100 feet. Metamorphosed.
Daspoort Quartzite ..	One quartzite. Approximate thickness, 250 feet. Not metamorphosed.	One quartzite. Approximate thickness, 80 feet. Metamorphosed and sheared.
Timeball Hill Quartzite ..	Series of thin partly magnetic reddish quartzites. Not metamorphosed.	One non-magnetic light coloured quartzite. Approximate thickness, 120 feet. Not metamorphosed.

The *shales* show an extraordinarily variable development, and fall into two groups of very unequal importance. The great bulk of the shales are more or less strongly metamorphosed, and north-west of the Motse River the alteration becomes so pronounced, that the resulting rocks have lost all their original characters and represent crystalline schists, the bedding planes becoming planes of schistosity. The second division consists of shales, little or quite unaltered; these are very subordinate and restricted to the horizon below the Timeball Hill Quartzite, and then only occur as far north as the junction of the Steelport and Oliphants Rivers. As developed in the Ohrigstad Valley, the shales are still typical aluminous rocks, in every respect similar to those of the same horizon in the Central Transvaal, but towards the Steelport River and a little beyond a gradual change to less shaly types is quite evident. Over the farms Kromellenboog, Kranskloof, and Weltevreden occur light pinkish to greyish blue more sandy shales, with minute muscovite flakes on the bedding planes.

A remarkable feature of the Pretoria Series north-west of the Steelport River is the abundance of *ferruginous slaty quartzites*, which assume considerable proportions along the southern parts of the Haenertsburg Gold-fields. They are only met with below the Timeball Hill Quartzite, and form a continuous band of great thickness from the right bank of the Motse River north-westwards as far as the area has been examined. Along the Malips River their thickness is not less than 3,000 feet. They form a very uniform succession of

extremely hard, rather thinly bedded fine-grained slaty quartzites, usually pale reddish-yellow in colour and well banded, owing to the great prevalence of very regular bands of magnetite arranged parallel to the bedding planes, and varying in thickness from a quarter of an inch down to mere films. Locally the rock may turn into a more thinly bedded, less well-banded type, more slaty in structure and dirty yellow in colour, when the wider bands of magnetite are missing, but numerous extremely well-formed octahedra of magnetite occur scattered through the rock. Sometimes thin bands are found, interbedded with the common slaty quartzites, which are still slightly shaly; in such cases the latter are usually very dark greenish, and sometimes crowded with scattered stellate tufts of delicate yellowish fibrous needles of actinolite; long slender needles of decomposed yellow chiastolite up to half an inch in length also occur, but quite subordinate. The most striking feature along this horizon is the abundance of yellow and blue crocodolite and yellowish asbestos, in places several inches thick (see later under Economic Geology); the various types referred to can be well studied along the right bank of the Oliphants River, south of its junction with the Motse River, notably on the farm Pendge.

Although the phenomena of contact and, to some extent, dynamic metamorphism are very strongly developed in this part of the Eastern Transvaal, there is no evidence to suppose that the continuous but rapid transition of the sandy shales into the slaty ferruginous quartzites is due to these agencies. The distribution of the rocks rather points to a change in the character of sedimentation from the Steelport River north-westwards, which soon after its initiation became permanently established and continued at least as far as Chunies Poort. Undoubtedly the ferruginous quartzites did suffer subsequent alteration due to intrusive igneous rocks, just like the other members of the Pretoria Series, as shown by the occasional development of fibrous actinolite, chiastolite, and magnetite, but the very character of these slight mineralogical changes shows that the influence can only have been a feeble one, and must have occurred at a stage, when the beds below the Timeball Hill Quartzite were already in essentially the condition we now find them in, for the nature of the ferruginous bands is clearly that of contemporaneous sedimentary iron ores.

The presence of a great succession of typical banded ferruginous quartzites in the Pretoria Series is of more than purely local importance, on account of the general resemblance which such rocks bear to certain widespread and well-known types of older rocks, e.g. Hospital Hill Slate and banded ferruginous rocks of the Swaziland Series. Where, as in the Red Granite area of the Bushveld near the junction of the Crocodile and Aapies Rivers,* the Pretoria Series occupies an abnormal position and not connected with the main outcrop in the Central Transvaal, the prevalence of such banded ferruginous quartzites might lead to a wrong view of their stratigraphical horizon.

(d) Metamorphic Rocks of the Pretoria Series.

(1) *General Remarks.*—There is probably no other area in the Transvaal where the variety and extent of metamorphic rocks surpass those of the district forming the subject of the present Report. Some idea of the extraordinary abundance and importance of these altered rocks may be gathered from the fact that from the top of the Pretoria Series downwards, through a thickness of at least 3,000 feet, the rocks have been more or less completely changed. Thus one finds an area of some 250 square miles made up of an extremely variable series of "spotted" slates, chiastolite and staurolite slates, sheared quartzites, sericitic quartz schists, mica and sericite schist, andalusite-hornfels, cordierite gneisses, etc.; and it is very interesting to bear in mind, that this collection of secondary rocks represent altered shales and quartzites, which can be readily correlated with definite horizons in the analogous but less altered series in the Central Transvaal. The possibility of tracing almost step by step the gradual passage of a typical shale into a holocrystalline cordierite contact gneiss, the clear manner in which the agents of metamorphism can be recognised, the evident connection between the presence of intrusive igneous masses and the occurrence of tectonic disturbances, the great variety of fresh and well exposed types of contact metamorphism, are features which give to the rocks of this portion of the Eastern Transvaal a more than purely local interest, and make the region one of particular importance to the geologist from the point of view of the genesis of crystalline schists.

Both the quartzites, as well as the shales, have undergone metamorphism, which has also affected an interbedded sheet of contemporaneous volcanic tuff, best developed near the Steelport River. It will be shown later that as the altered rocks are traced from the area across the Motse River into the southern portions of the Haenertsburg Gold-fields, east of Malips Drift—that is, from an undisturbed to a highly folded area—the nature of the metamorphism undergoes a very marked, though gradual, change, resulting in the prevalence of gneisses and schists.

(2) *Description of the Altered Beds.*—Since the great majority of these were originally ordinary shales, the character of the alteration depends not so much on the nature of the parent rock as on the position each

* See W. A. Humphrey, Annual Report of Geol. Survey for 1906, p. 112.

bed occupies with reference to the intrusive sheets and the edge of the Bushveld Plutonic Series. In the following account of metamorphism it is therefore more convenient to consider the altered rocks as developed along certain horizons, determined by the three leading quartzites and by the presence or absence of tectonic disturbances, which tend to modify more or less strongly the results of pure thermal metamorphism.

(i) *Altered Rocks above the Magaliesberg Quartzite.*—In several places along the margin of the Bushveld Plutonic Series and overlying the main Magaliesberg Quartzite occur outcrops of a very fine grained dark greyish holocrystalline rock, which, owing to the abundant development of minute biotite, possesses a highly lustrous appearance. They are best exposed on the farms Groothoek (171), Schlickmanns Kloof (12), and Derde Gelid (141), north-west of Fort Burger, but also occur along the right bank of the Oliphants River, east of Malips Drift. Everywhere these rocks directly overlie the Magaliesberg Quartzite, and dip below the Bushveld Plutonic Series in conformity with the general structure of the Transvaal System. While in the hand specimens there is a resemblance to intermediate plutonic types, such as finer grained diorite, and no indication whatever as to their true nature, the distinctly bedded character points to a sedimentary origin. On Derde Gelid and Groothoek are found good contacts, showing a very sharp junction with the basic facies of the Bushveld Complex, and on the last-named farm, as well as over the central portion of Schlickmanns Kloof, the rocks attain a thickness of several hundred feet, and are excellently exposed in a series of gulleys leading from the high plateau, floored by the Magaliesberg Quartzite, westwards to the low ground of the Bushveld country.

This type of metamorphic rock has been referred to as the *Groothoek* type,* as it is well exposed and in direct contact with the overlying igneous rock on that farm; the best outcrop occurs on the road about half a mile south of the store and twelve miles due north-west of Fort Burger. Microscopically it is very uniform in character, specimens from the Fort Burger area being indistinguishable from those seen near Malips Drift; it is a very hard fine-grained dark greyish type, with no minerals visible to the naked eye, excepting minute specks of black mica. A constant feature is the well-bedded character, nowhere better displayed than in the hilly tract west of Schlickmanns Kloof. Here occur a few instances of veining; the bedding planes are cut more or less at right angles by rather coarse igneous veins of a light coloured association of quartz, orthoclase, and black vesuvianite, averaging half an inch in thickness. Other veins consist practically entirely of greenish actinolite. Possibly these veins are connected genetically with the igneous mass which produced the metamorphism. Very frequently the weathered surface of the metamorphic rocks shows well developed alternating light and dark coloured bands, varying from half an inch in thickness to thin films, which indicate bedding planes of the original unaltered rock. A reference to the map on Plate IX, shows that in the Schlickmanns Kloof district a number of these additional quartzite bands are found at a higher horizon than the Magaliesberg Quartzite; followed along the strike they soon die out, so that the intrusive rock lying between them is really part of the main Bushveld Plutonic Complex; hence it is this agency that has produced the metamorphism.

Thin sections of the Groothoek type show a very close general similarity, even when coming from outcrops wide apart, and indicate a granular holocrystalline rock. The texture is extremely even grained in any one slide, but there is some variation in the degree of fineness; the average size of the grains is ·07 millimetres. The following minerals occur in order of abundance:—Biotite, quartz, cordierite, felspar, hornblende, tourmaline, and corundum. Of these the first four are universally present, while the remainder are less abundant. Biotite forms small greenish-brown short lath-shaped crystals, showing intense pleochroism and a habit typical of its thermo-metamorphic origin. The individuals are very uniform in size and practically free from inclusions. The main bulk of the sections is generally made up of a very clear and fresh evenly developed slightly coarse and colourless mosaic of quartz, felspar, and cordierite (see Plate V, Fig. 4.) As all the three minerals have refractive indices not widely different from one another, their identification is not always simple; the felspar, for example, can only be recognised by tests in convergent light, and its identity as albite has to be largely inferred from chemical analysis. Cordierite occurs in rounded to rectangular colourless sections, possessing a slightly higher index of refraction, which, together with the faint yellow tints under crossed nicols, help to single it out. Occasional sector twinning, the character of the axial figure, and the very numerous inclusions, mainly of quartz and biotite, produce a characteristic set of diagnostic properties, though the blue colour and marked pleochroism found in cordierite of volcanic origin are absent, and also the yellow halos noticed by other writers in metamorphic cordierite are feebly developed. The presence locally of abundant pyroxene and greenish blue amphibole is unusual, and may be due to a slight transference of the material form the basic margin of the Bushveld Complex. The presence of tourmaline is of considerable interest. This mineral is widely distributed, but always in small quantities. It occurs in more or less idiomorphic pleochroic

* A. L. Hall, "On contact metamorphism in the Pretoria Series of the Lydenburg and Zoutpansberg Districts," Trans. Geol. Soc. S.A., 1908, vol. xi.

bluish crystals slightly elongated along the principal axis, parallel to which there is the typical deep blue absorption tint, i.e. when the optic axis lies at right angles to the plane of vibration of the polarizor; such crystals are sometimes terminated by faces belonging to the fundamental rhombohedron. Highly characteristic trigonal and hexagonal sections are sometimes found. Corundum occurs only in small colourless, scattered, highly refractory grains, though below the horizon of the Magaliesburg Quartzite it is found in flat rudely hexagonal plates, visible in the hand specimens.

At the actual contact and for about 2 feet from it, this type of metamorphic rock is rather different mineralogically. The rock has the same appearance, but, apart from the colourless quartz-felspar mosaic, pyroxene and minute biotite laths are the only minerals met with, the former in very plentiful colourless small grains. The appearance of the intrusive igneous rock is very peculiar in those sections cut across the line of contact; there is a distinct tendency to orientation of the biotite laths, and to a lesser extent of the pyroxene, and it looks as if intrusion occurred under some pressure. Probably such inclination towards a kind of foliation is analogous to the same effect seen in the foliated norites which have been noted at several places* along the eastern margin of the Bushveld Plutonic Series. The point will be again referred to when the general metamorphic history is reviewed.

On Schlickmanns Kloof (12) and Derde Gelid (141), where the plateau begins to descend towards the Bushveld country on the west, peculiar finely banded rocks were met with. These are dark coloured, compact, serpentine-like rocks, individual bands not exceeding one-quarter of an inch in thickness; under the microscope the rock shows alternating layers of igneous and metamorphosed sedimentary material; the former made up entirely of colourless serpentine with good mesh structure, the latter of finely granular pyroxene-hornfels, in every respect similar to that developed along the main contact further west (see Plate VI, Fig. 1). There is little doubt, therefore, that such banded rocks are in reality shales repeatedly and regularly injected with basic rock.

It follows from the above description that the *Groothoek* type of metamorphic rock represents a highly altered shale, characterised mineralogically by the abundance and universal presence of biotite and cordierite, structurally by the well-marked, evenly granular appearance ("Pavement Structure") and the sieve-like inclusions in some of the metamorphic minerals. The original character of the unaltered rock is completely lost in the hand specimen. As the term hornfels has been used somewhat loosely and does not in any way indicate the nature or origin of such rocks, the term cordierite contact fels—in the sense first used by Salomon†—is more appropriate.

(ii) *Metamorphic Rocks below the Magaliesberg Quartzite in the Undisturbed Area.*—These comprise a great variety of types, the majority of which still show their shaly origin in the hand specimens, and differ from the preceding Groothoek type by very commonly containing numerous conspicuous metamorphic minerals, visible to the naked eye and occasionally very large, such as staurolite, chiastolite, andalusite, and garnet. One particular horizon—that is, the first series of altered shales below the Magaliesberg Quartzite—consists entirely of dark greyish crystalline hornfels, with a mineralogical composition intermediate between that of the Groothoek type and that of the obviously shaly rocks along lower horizons. To the latter the name *Longsight* type has been applied,‡ as they are typically developed and were first met with in very good exposures on the farm Longsight, north-west of Ohrigstad. The phenomena are furthermore complicated by pressure metamorphism, which begins to show a little north-west of the Motse River, and its effects become more and more pronounced the further the beds are traced into the folded area over the southern portions of the Haenertsburg Gold-fields, and, since the final products are very different in character from the rocks as developed in the undisturbed area south of the Motse River, it is convenient to describe them separately.

From the neighbourhood of Lydenburg to near Malips Drift the main Magaliesberg Quartzite is invariably underlain by a fairly thick intrusive sheet, the lower edge of which is in direct contact with a uniform series of finely granular dark greyish crystalline hornfelsic rock bearing a very close general resemblance to the altered shales above the Magaliesberg Quartzite, which are in contact with, and owe their metamorphism to, the main body of the Bushveld Plutonic Series. The larger portion of this series very closely resembles the hornfels type previously described, in showing no microscopic minerals excepting abundant minute biotite, and in having lost all characteristics of the original shaly nature. But towards the base, types come in distinctly coarser and with much conspicuous andalusite, and occasionally corundum in certain bedding planes, in the form of rudely hexagonal thin plates clearly shown in the hand specimens. Therefore it seems probable that so intense a degree of metamorphism could not have been produced by the thermal effects of the intrusive

* H. Kynaston, "On certain Rocks associated with the Norite and Granite of the Central Transvaal," Trans. Geol. Soc. S.A., vol. viii. p. 59., 1905.

† W. Salomon, Petrog. und Geol. Stud. am Monte Avio'o im italienischen Anteil der Adamellogruppe. Z. d. d. G. G., 1890.

‡ A. L. Hall, *loc. cit.*

sheet alone, but was assisted by the direct influence of the main body of the Bushveld Plutonic Series. This question will arise again, when the metamorphism of the folded area is discussed; there, at any rate, the arguments are much stronger in favour of the view, that the heat of the Bushveld Plutonic Series proper travelled some way downwards into the Pretoria Series.

Both sides of the Spekboom River Valley, as well as the area immediately east of the Tokane Mountains, north-west of the junction of the Steelport and Oliphants Rivers, afford numerous very good outcrops of the rocks under consideration. Along the western portions of Putney (808) and Wimbledon (806) the best instances are found of the change near the base from the Groothoek to the Longsight forms. While, as a whole, the macroscopic character of this horizon of altered shales is everywhere the same from the upper parts of the Spekboom River Valley to the Motse River, and very similar to the form of Groothoek type described above in section (i), one finds occasionally a variation due to the peculiar mode of occurrence of sillimanite. On the farm Mooifontein (221), south of Fort Burger, on the left side of the Spekboom River, occur peculiar strikingly spherulitic rocks, containing numerous well-rounded opaque dirty white spherulites of fairly uniform size, averaging three-sixteenths of an inch in diameter. These are dense aggregates of sillimanite, with associated biotite and quartz.

Thin sections examined under the microscope show the following minerals in approximate order of abundance:—Quartz, biotite, cordierite, felspar, andalusite, sillimanite, and garnet. The four first-named minerals are present in every section; the biotite closely resembles that of similar rocks previously described, except that it seems to contain inclusions more plentifully and possesses in a greater degree the deep brown tints characteristic of contact metamorphic biotite. Quartz and felspar are invariably associated in a very fresh, clear granular mosaic, well shown under crossed nicols; the latter mineral shows no crystal outline, no decomposition products or twin lamellæ; it therefore can only be recognised as a biaxial mineral by means of convergent light. A quantitative analysis of an occurrence from the Spekboom River Valley showed no potash, but 1·85 per cent. of soda, which suggests albite as the constituent felspar. Cordierite is invariably riddled with very numerous inclusions, mainly of quartz and biotite, and possibly corundum. Its recognition depends on the same properties above described. Andalusite occurs in large rudely rectangular phenocrysts, which stand out in bold relief by their higher refractive index, and have a kind of worm-eaten appearance, while the edges of the crystals are crenulated in a distinctive manner. Garnet was found in isolated idiomorphic colourless grains from exposures on the farm Wimbledon. Sillimanite is of purely local occurrence and invariably found in aggregates of very delicate curvilinear tufts intimately associated with the biotite, which often feathers out into almost hair-like and sinuous needles of this mineral. Usually the concentration goes so far as to produce knots or spherulites readily visible in the hand specimens, and showing upon the fresh surface as dirty opaque white spots, which, under the microscope, consist mainly of sillimanite needles associated with biotite and quartz.

The structure is holocrystalline, but when the andalusite phenocrysts become larger the appearance tends to become porphyritic. The fresh mosaic exhibits good pavement structure, and the strongly marked sieve structure of some of the metamorphic minerals is again noticeable. The mosaic represents the completely recrystallised slaty material of the parent rocks. The clear way in which, sometimes, the biotite flakes wrap round and enclose the cordierite suggests that the latter was formed before the majority of the mica.

It follows from the above that this horizon of altered shales belongs to a transition rock, connected structurally with the Groothoek type, but mineralogically inclining to the Longsight type on account of the presence of macroscopic andalusite. The quantitative analysis referred to gave the following approximate composition in terms of constituent minerals:—

Quartz	29·3 per cent.
Cordierite	23·9 „
Biotite	17·6 „
Albite	15·9 „
Andalusite	9·8 „
Total	96·5 per cent.

Garnet, sillimanite, and magnetite were not taken into account owing to their comparative scarcity.

The great bulk of the remaining altered shales between the Magaliesberg and Daspoort Quartzite from horizons below that of the transition rock just described belong to the Longsight type, and nearly always show in the hand specimen conspicuous typically metamorphic minerals, such as staurolite, andalusite, and chiastolite, while the groundmass is much less recrystallised, so that even without microscopic examination they

are clearly recognisable as altered shales. Such rocks are well exposed north-west of Ohrigstad, where they were first discovered, and referred to in the Annual Report of the Geological Survey for 1906 (page 90). From this neighbourhood they extend north-westwards, and preserve always very similar characteristics, so long as they remain in the undisturbed area. The intrusive sheets present throughout the series are probably sufficiently numerous and thick to account for the metamorphic phenomena; and since, moreover, there is a direct connection between the degree of alteration and the distance from any one intrusion, it is clear that the influence of the main body of the Bushveld Plutonic Series did not extend any great distance into the Transvaal System, probably no further than about half-way between the upper and middle quartzites. Immediately at, and close to the contact, one finds very hard tough compact siliceous bluish grey hornfels, showing no new minerals of any kind. This type rapidly gives place to more obviously slaty rocks of the Longsight type, more or less crowded with conspicuous metamorphic minerals, such as staurolite, chiastolite, and andauslite. Evidently the unaltered shales must have been susceptible to contact metamorphism in a very variable degree, for some times typical chiastolite slates, comparatively little recrystallised and containing mainly long needles of chiastolite, show thin bands only 1 or 2 inches in thickness, composed throughout of holocrystalline fine-grained hornfels of the Groothoek type, with cordierite, staurolite, garnet, biotite, chlorite, andalusite, and amphibole.

It is not possible in the present report to describe all the numerous varieties of altered shales which are included in the Longsight type, and it will suffice to give an account of their development along the Motse River Section and the surrounding district, which covers the horizon from the base of the Daspoort to the top of the Timeball Hill Quartzites, over the south-western portion of the farm Havercroft, close to the junction of the Motse with the Oliphants River. The rocks are exposed in the bed and on the banks of the former, along one continuous section terminated above and below by intrusive sheets, while the extensive slopes in contact with the escarpment of the Daspoort Quartzite, especially towards the head-waters of the Toxitse Spruit, exhibit a succession of striking metamorphic rocks, which it would be difficult to surpass anywhere in variety and freshness. These altered shales are well bedded light greyish to deep bluish purple in colour, with a typical fine-grained shaly groundmass, in which are set the following metamorphic minerals:—Staurolite, chiastolite, andalusite, and biotite, with occasionally garnet in small but distinctly visible grains. Cordierite also occurs, but only in the hornfelsic bands, and never recognisable in the hand specimen. Almost invariably staurolite and biotite, and to some extent andalusite, occur plentifully; occasionally in densely crowded aggregates, and often these minerals attain large dimensions. At one point in the Motse River Section the bedding planes of the dark coloured slab are crowded with striking needles of chiastolite up to 3 inches in length. Sometimes they tend to radiate from a point, which has given rise to their local designation as foot-prints of birds. The crystals have the typical resinous appearance, and on a fresh fracture sometimes exhibit the well-known graphitic centres. Staurolite sometimes is found in long black crystals up to 2 inches in length, showing the various kinds of cruciform interpenetration twins. When it is smaller the colour is uniformly brown, as along the left bank of the Toxitse Spruit. Dark greenish or black biotite is never absent, and forms, in fact, the one universally present metamorphic mineral to be found in all altered shales throughout the whole district. Andalusite is more restricted and appears in the form of elongated opaque whitish tabular crystals. Cordierite and garnet are practically confined to the thin bands of Groothoek type, intercalated among rocks of typical Longsight character. A very good instance of this occurs in the Motse River Section along the left bank of the stream, where it makes a sharp bend; here a fine succession of dip slopes are exposed, densely covered with chiastolite needles. Vein-like bands parallel to the bedding planes occur, and are easily distinguished by the sudden appearance of crowded granular red garnet in a compact fine-grained completely crystalline matrix. Under the microscope such bands are made up of an entirely recrystallised fresh fine-grained quartz-felspar mosaic, in which occurs garnet in excellent idiomorphic crystals traversed by chlorite veins, cordierite, and a little staurolite possessing pronounced sieve structure.

Thin sections of the various types of less altered shales indicate, that the original rock is less recrystallised. The universal metamorphic mineral biotite is the most obvious constituent; next comes staurolite, always in well-marked idiomorphic crystals with excellent rhombic section, characteristic pleochroism, and multiple twinning—its recognition offers no particular difficulties. The graphitic inclusions in the chiastolite sometimes give rise to very symmetrical forms, which are always very pronounced. Andalusite is less common, but usually present with elongated rectangular habit, and so full of inclusions as to resemble the appearance of cloudy orthoclase of some plutonic rocks (see Plate V, Fig. 3).

It was pointed out above, that below the Timeball Hill Quartzite the bulk of the rocks belonging to the Pretoria Series are banded ferruginous slaty quartzites. Shales are quite subordinate, and only found overlying the thin intrusive sheet which is commonly present near the base of the series.

Another subordinate intrusion was found a little below the base of that quartzite, and is well exposed along the southern portion of the Haenertsburg Gold-fields, e.g. in Lot No. 276. The altered shales are pale grey coloured staurolite slates, with chiastolite and biotite visible in the hand specimen. In this horizon, too, are found thin bands, hornfelsic in character and resembling Groothoek types in appearance; as usual, cordierite predominates in them. Thin sections examined under the microscope show characters very much like analogous metamorphic staurolite rocks of the Motse River Section, excepting that another mineral is very largely found in small idiomorphic, shortly prismatic, colourless, highly refracting crystals, possessing low double refraction. This is probably zoisite. Sieve structure, as usual, is very much in evidence in all the metamorphic minerals, especially in staurolite. It has occasionally gone so far, that it is sometimes very difficult to realise the original connection—proved under crossed nicols—of numerous isolated and scattered grains.

Even the banded ferruginous rocks are not quite free from metamorphic effects, especially where they are locally still slightly shaly. Their general appearance has remained practically unaltered, but the formation of new minerals is noticeable in the presence of slender short chiastolite needles, and of stellate groups of pale brownish needles of a mineral answering microscopically to actinolite.

The Metamorphism of the Quartzites and Greywackes is well shown in the Daspoort, less so in the Magaliesberg, and not noticeable in the Timeball Hill Quartzite. In any case contact metamorphism would be less marked on account of the highly siliceous nature of such rocks, which renders them incapable of undergoing pronounced molecular rearrangements of a kind to produce new minerals. On the other hand, deformation leaves more striking results on the quartzites than on the shales, as will be shown later. When the former are pure, the alteration does not go further than produce a very fresh glassy looking rock, but the more impure the quartzite the more variable are the metamorphic effects. An interesting series of changes occurs in connection with the Daspoort Quartzite, where it is cut through by the Motse River. Near the common beacons of Havercroft, Putney, and Stellenbosch the following kind of alteration is observed:—Near the base of the Daspoort Quartzite escarpment the rocks assume a darker colour, become more fine grained, but, excepting a few scattered small flakes of white mica, shows no new minerals in the hand specimen. Thin sections show the characters of quartzitic rocks, with a fair amount of metamorphic biotite in large crystals and small grains of magnetite with good idiomorphic outlines. Between the quartz grains secondary filmy sericitic mica is freely developed, while one section shows irregular grains of epidote. This type passes rapidly downwards into a band about 6 inches thick of a light coloured very peculiar rock, composed mainly of crowded flakes of a white sericitic mineral, and, but for the fact that it is not in any way foliated, the rock resembles a fine-grained muscovite or sericite schist. The thin section shows practically nothing but densely packed delicate colourless needles of sericitic mica, in which two or three quartz grains can be observed. This type is very unusual, though altered Pretoria Quartzites have been found, rich in metamorphic mica, in the norite north-west of Pretoria.* The above band is underlain without any sharp junction by one about 8 inches thick, and belonging to a compact dark coloured hornfelsic looking rock, which probably represents a very impure shaly horizon at the bottom of the main quartzite. The bulk of the section consists of pale granular epidote, in which lie very fresh quartz grains. Deep brown irregular crystals of biotite, a little wedge-shaped sphene, and sharply pleochroic bluish hornblende, resembling glaucophane, also occur. The above type is in fairly sharp contact with a series of underlying fine-grained dark coloured rocks about 20 feet thick, which behave in the field like an intrusive sheet and form a strong contrast with the overlying light coloured quartzite. The hand specimen is densely crowded with short and very delicate needles of black amphibole. It is not certain, however, whether this rock is sedimentary or igneous. Under the microscope the upper portion, which adjoins the overlying type just described, consists very largely of a strongly pleochroic idiomorphic bluish amphibole, with a scheme of pleochroism resembling that of glaucophane, set in a rather siliceous groundmass, of which quartz is the only mineral definitely recognisable. As one descends lower down, the rock contains less and less glaucophane-like amphibole, while small brown and strongly pleochroic metamorphic biotite begins to appear. At the same time the siliceous looking groundmass appears more like a recrystallised originally felspathic mosaic. The above features seem to suggest that the rock corresponds to a highly metamorphosed greywacke type, such as one finds in the same position below Meintjes Kop at the Capital.

It will be shown below that a remarkable dark coloured rock occupying a similar horizon and full of undoubted glaucophane occurs in the southern portion of the Haenertsburg Gold-fields.

(iii) *The Mica Schists, Cordierite Gneisses, and Sheared Quartzites in the Disturbed Region.*—The occurrence in the Pretoria Series of rocks resembling crystalline schists and interbedded in strict conformity with the general

* Annual Report of Geol. Survey for 1905, pp. 36 and 69.

structure of the Transvaal System has not been known hitherto*, and is of particular interest on account of their evident connection with the movements affecting the Transvaal System, as a result of the intrusion of the Bushveld Plutonic Series.

The rocks now under review occur from the base of the Magaliesberg down to the top of the Timeball Hill Quartzite, and are well exposed over the southern portion of the Haenertsburg Gold-fields, westwards from the junction of the Oliphants with the M'Thlapitsi River. While there is a fundamental structural difference between these schistose rocks and those of the Longsight type described in the previous section, the change is not abrupt, but is developed gradually, and becomes increasingly more marked as the strike of the Transvaal System turns more towards the west, and is finally established in the angle of bend between the Drakensberg and Strydpoort Ranges, that is, in the most disturbed area.

It was stated above, that there is abundant field evidence to show, that the Transvaal System as a whole has been subjected to considerable pressure, and especially the lower part of the Pretoria Series together with a portion of the Dolomite are thrown into powerful and repeated folds. It is clear, that such a factor must leave its mark on the rocks affected. Furthermore, the harder the rock, within limits, the more clearly should the influence of pressure be shown. It will be sufficient, therefore, to trace the character of the Daspoort Quartzite as developed in the disturbed and the normal areas. The latter extends north-westwards to about the junction of the Motse and Oliphants Rivers, but in the nature of the case there can be, and is, no sharp demarcation. Where the structure is free from tectonic disturbances, the Daspoort Quartzite in the hand specimen is practically indistinguishable from the same rock as found along the type section west of Pretoria, while in thin section it shows the usual granular structure of the quartz without strain shadows. A little strongly pleochroic metamorphic biotite has been found. East of Malips Drift, the same rock loses its granular appearance and has a distinctly schistose character, individual quartz grains becoming drawn out into lenticular shapes, while parallel to the bedding planes very thin filmy pale greenish, or almost colourless sericite is developed. In thin section, cataclastic structures are obvious and produce a finely granular mosaic round the larger grains (Mortar Structure), while strain shadows are abundant. Sometimes deformation has gone even further, with the result that the rock becomes thrown into minute folds along the bedding planes, resulting in a kind of secondary cleavage. The abundance of filmy pale green sericitic mica gives rise to a somewhat silky lustrous appearance resembling that of fine-grained mica schists. Strain shadows, the way in which each grain has become flattened, the linear arrangement of the colourless mica, the denser aggregation of the bedding planes in the common limb of the folds, the occurrence of " eyes " of more granular less sheared portions of the normal rock, all point conclusively to the fact that intense pressure has acted on this rock (see Plate VI, Fig. 2). Occasionally tourmaline is found. The presence of this mineral is of importance, for it is not one which can in any way be said to be typical of dynamic metamorphism, but is essentially a contact mineral. It always occurs in extremely small quantities, but rather widespread; the commoner habit is that of strongly pleochroic bluish crystals, slightly elongated parallel to the axis, with the strongest absorption when its length is perpendicular to the plane of vibration of the polariser. Now and then small deep coloured characteristically nine-sided isotropic sections are met with. The wider significance of this mineral for the general history of the metamorphism is considered below.

Hence we must conclude that the Pretoria Series in this part of our area has been subject to strong pressures.

In addition to the quartz-schists and sheared quartzite just described, the disturbed area contains a number of highly altered more or less completely crystalline rocks with pronounced schistose or gneissic structure. These may be divided into (1) Mica and Sericite Schists, and (2) Cordierite contact-gneisses; on the whole they bear a strong resemblance to so-called crystalline schists.

Mica and Sericite Schists.—The group of Mica and Sericite Schists (see Plate VI) are best seen below Kodoe Kop (on the north side), a prominent range belonging to the Magaliesberg Quartzite, situated about half a mile east of Malips Drift, and below the Daspoort Quartzite in the same neighbourhood, especially on Lots Nos. 253 and 260. Another fine series of outcrops occur along the right bank of the Oliphants River over the northern portion of Haakdoornhoek (607). Since the Pretoria Quartzites are topographically very prominent, it is in proximity to them and on the escarpment side, that the schists are best exposed, for the intervening valleys show practically nothing but thick deposits of deep red sand. No doubt the presence of massive quartzite has protected the schists from more rapid erosion. Near Kodoe Kop and Haakdoornhoek they are dark greyish brown, thoroughly schistose, more or less foliated rocks, in which talc, white mica, and black mica are abundant. The prevalence of the first two minerals gives them sometimes a brilliant lustre, especially

* See Molengraaff.—" Note on some rock specimens exhibited at the meeting of the Geol. Soc. of S.A. in Feb., 1905." Trans. G.S.S.A., VIII, 1905, p. 64.

as the talcose flakes may be up to quarter of an inch wide. In places the schistose structure is less strongly developed, when the appearance is closely similar to the more granular hornfelsic rock described above as representing the Groothoek type, from below the Magaliesberg Quartzite, south-east of the Motse River. The schists at Kodoe Kop represent this identical band. Close to the store on the left bank of the Malips River the mica schists appear interbedded with thin light coloured medium grained bands composed mainly of quartz and felspar, varying from a quarter of an inch in thickness down to mere films. The appearance and behaviour of these veins suggests, that they are due to igneous material injected into the schists, in the same way in which the altered rocks in the Schlickmann's Kloof district sometimes show repeated injection on a small scale. In the first group the following minerals occur in thin sections: Muscovite, biotite, sericite, quartz, cordierite, sillimanite, felspar, zircon, and tourmaline. A variety of structural features are found strongly marking the schistose character. The black mica is nearly always arranged with a pronounced parallelism; it frequently also becomes arranged in the forms of well marked "eyes," enclosing muscovite, cordierite, and recrystallised mosaic. The rock throughout is quite fresh, and shows all the characters of an intensely contact-metamorphosed shale with schistose structure. On the other hand, mechanical deformation is not noticeable under the microscope; the minerals do not appear bent, cracked, or displaced on a small scale. Biotite is the most abundant contact mineral, making up quite half the slide, and occurs in exceedingly well oriented deep brown lath-shaped and fresh crystals giving very strong pleochroism, with occasional inclusions of zircon. The mineral is commonly associated with muscovite, and frequently in parallel intergrowth with the latter. Sillimanite is found in more or less dense aggregates and apparently connected genetically with biotite, as it usually forms whisps or tufts of numerous very slender needles, sometimes a little curved, passing out from the biotite laths. The colourless portion of the section consists of a granular mosaic of quartz and a perfectly fresh transparent mineral, with a faint kind of twin lamellation—probably this is albite. A few colourless sections occur and behave like microcline. In the groundmass are found a few irregular crystals of cordierite with very striking sieve structure. The presence of tourmaline deserves special mention, as it strongly suggests the essentially contact metamorphic origin of this group of schists. Since it is coloured deep greenish brown, and forms a fair number of small but idiomorphic characteristic nine-sided sections, its diagnosis is not difficult, especially as in one or two instances one also finds slightly elongated crystals, which these show, the well marked absorption direction. A very striking rock occurs immediately underlying the Daspoort Quartzite, a little east of Malips Drift. It is a highly lustrous silvery white thinly schistose and soft sericite schist, with scattered short needles of chiastolite. Under the microscope practically the entire slide consists of sericite. Below the same quartzite, but a little lower down, is found, on Stavenhagen, not far from the junction of the M'Thlapitsi and the Oliphants Rivers, another remarkably fine type of crystalline schist, beautifully mottled in appearance. It is a pale silvery grey soft rock, composed of filmy sericite and crowded with minute biotite flakes. The presence of knob-like crystals of garnet give rise to a peculiar knotty appearance. The horizon is the same as that of the dark blue staurolite and chiastolite slate of the Motse River section.

Mention must be made finally of a peculiar compact deep bluish rock found near Lot 265, a little way below the Daspoort Quartzite. Its exact horizon, however, is not certain, but it answers closely to the rocks mentioned above as carrying glaucophane-like amphibole, and described in connection with the altered greywackes. In the hand specimen is seen a greyish metallic looking mineral, sometimes scattered, sometimes arranged in straight lines. There is a slight tendency towards a kind of stellate grouping along these lines; the mineral is very hard and strongly magnetic; the occasional brown decomposition products suggest an iron ore. Probably it is magnetite. The thin section consists mainly of fresh acicular glaucophane, showing a very strongly marked pleochroism with the characteristic bright blue tints—together with a little bright rusty-brown biotite. The very poorly developed groundmass seems rather quartzose. Altered rocks containing glaucophane appear to be confined to this particular horizon only, but its mode of occurrence agrees with that in mica-schists and allied rocks described from other regions.

The *gneissic* group of rocks lies a little beyond the western limits of the area dealt with in this report, but belongs undoubtedly to the same series of metamorphic rocks. They were first found by Mr. H. Kynaston,* and occur in a number of small isolated kopjes and minor outcrops scattered over the deep red soil of the flat portions in M'Phatlele's Location. The rock is a dark grey holocrystalline gneissic rock, and lies between the Magaliesberg and Daspoort Quartzites, along a horizon identical with that of the micaceous schists east of Malips Drift. Thin sections show abundant deep brown biotite, sillimanite, cordierite, some andalusite, a coarse granular mosaic of quartz and felspar, with grains of deep brownish green tourmaline in characteristic sections.

* H. Kynaston, "On Certain Rocks associated with the Norite and Granite of the Central Transvaal." Trans. Geol. Soc. S.A., 1905, vol. viii., p. 59.

In the southern portion of the Haenertsburg Gold-fields, the metamorphic rocks no longer have a pronounced resemblance to crystalline schists along horizons below the Timeball Hill Quartzite, but there they carry staurolite in great abundance, and nearly always in large black crystals some times over an inch in length. This mineral is confined to a distinctly lower horizon in the Pretoria Series, is only feebly developed between the Timeball Hill and Daspoort Quartzites, and altogether absent above the latter. On the other hand sillimanite is always present between the Magaliesberg and Daspoort Quartzites, yet does not occur further down. Hence there is a fairly sharp distribution of staurolite and sillimanite depending upon the distance of any one horizon of altered rocks from the margin of the Bushveld Plutonic Series. Cases like this are well known in connection with large bodies of intrusive masses, a good example having been described from the south-eastern Highlands of Scotland.*

3. *Distribution of the various types of Altered Rocks.*—All the various kinds of metamorphic rocks can be arranged into three groups, more or less sharply distinguished from one another, though naturally one group may merge gradually into another. These groups are :—

(*a*) The Groothoek type.
(*b*) The Longsight type.
(*c*) The Malips River type.

The leading characters, horizon, and distribution of each of these may be *summarised* as follows :—

(*a*) *The Groothoek type.*—These are light or dark grey, sometimes almost black, rocks, possessing a medium to fine-grained holocrystalline structure, and a highly characteristic glittering appearance. Macroscopically, small crowded flakes of biotite and white spherulitic aggregates of sillimanite are visible. Microscopically they consist essentially of biotite and cordierite, with sillimanite and tourmaline as accessory minerals. A granular quartz-felspar mosaic is universally present.

This type was produced by contact metamorphism from ordinary Pretoria Shales, and is practically confined to the horizon above the Magaliesberg Quartzite, where the altered rocks are in direct contact with the margin of the Bushveld Plutonic Series—the latter is also the agent of metamorphism. The Groothoek type belongs to the Hornfels group of thermo-metamorphic rocks, but there is no longer any horny appearance noticeable. From the Steelport River to the neighbourhood of Malips Drift they present very uniform characters, while their original nature is petrographically completely lost, only the good bedding still indicating a sedimentary origin. Locally these rocks may have a thickness of at least 200 feet.

Occasionally the same type is found at various horizons between the Magaliesberg and Timeball Hill Quartzites, but such occurrences are quite local, the hornfelsic bands being only an inch or two thick.

(*b*) *The Longsight type.*—Under this name may be conveniently grouped together all such metamorphic rocks which are less altered than those falling into the previous group, and which are characterised by invariably showing numerous and macroscopically conspicuous contact minerals. To this type, therefore, belong Staurolite slate, Andalusite slate, Chiastolite slate, etc. These are always well bedded and without microscopical examination readily recognisable as altered shales. The minerals met with are, in approximate order of abundance : Staurolite, Biotite, Chiastolite, Andalusite, Garnet, Chlorite, and Cordierite. The groundmass is generally more or less strongly recrystallised, but never as much as in the Groothoek type.

The Longsight type never occurs above the Magaliesberg Quartzite, and is confined in its purest forms to the undisturbed area from the Motse River south-eastwards, along horizons from midway between the Magaliesberg and Daspoort Quartzites downwards, to nearly the base of the Pretoria Series. Often rocks of this type vary in character with the distance from an intrusive sheet; their contact alteration seems, therefore, due rather to these than to the margin of the Bushveld Plutonic Series.

Intermediate between (*a*) and (*b*) occur rocks forming a kind of transition zone, and confined to the first series of altered rocks below the Magaliesberg Quartzite. Structurally they lean towards the Groothoek type, but the more shaly character and presence of macroscopic andalusite at their base connects them with the Longsight group. Apparently both agents of metamorphism co-operated in producing this intermediate group.

(*c*) *The Malips River type.*—It is convenient to have a name under which the numerous habits of the schistose rocks can be embraced. As they are confined to the disturbed region over the southern portion of the Haenertsburg Gold-fields, and are typically developed in close proximity to the drift across the Malips River, the above designation has been chosen.

Pronounced schistose and gneissic structures are frequent, while the rocks are also thoroughly crystalline. The following minerals are met with :—Biotite, quartz, felspar, sillimanite, muscovite, garnet, chiastolite,

* G. Barrow, "On an Intrusion of Muscovite-biotite gneiss in the south-eastern Highlands of Scotland, and its accompanying metamorphism," Q.J.G.S., 1893, vol. xlix, pp. 330–354.

sericite, cordierite, and tourmaline. These rocks are essentially of contact metamorphic origin, but have become schistose owing to their having been altered while under pressure. Since they can be traced without any break into gradually less and less altered shales their sedimentary origin is beyond question.

Of these three groups, the first one is best defined, and there are few rocks where the question of their inclusion in that class is doubtful. On the other hand, the Malips River type is less well defined, which fact follows easily from the mode of origin of the rocks included under that name.

4. *The Agents of Metamorphism.*—The altered rocks may have been affected either by the main body of the Bushveld Plutonic Series or by the numerous intrusive sheets within the Pretoria Series, while one horizon seems to have been affected by both. The question now remains to be discussed, how far it is possible to estimate the share of each agent in producing the final results. So long as a variation in the degree of metamorphism with the distance from any one intrusive sheet is clearly recognisable, there is good reason to suppose that this has been the sole agent, for if the heat of the main body of the Bushveld were to any marked extent added, the metamorphism would tend to become more uniform in degree. A very good case in point is the thick sheet above the Daspoort Quartzite exposed along an extensive and striking escarpment north-west of Orighstad, where the gradual change in the altered rock is well shown. Also in most cases the intrusions are thick and numerous enough to account for the widespread occurrence of the Longsight type. The latter, therefore, is characteristic of contact metamorphism, with intrusive sheets as the main agent. This statement probably holds good as far north-westwards as the neighbourhood of the Motse River.

On the other hand, all the rocks of the Groothoek type lying above the Magaliesberg Quartzite are very similar in character and in direct contact with the basic margin of the Bushveld Plutonic Series. Therefore, no doubt can be felt, that the latter has been the sole agent of metamorphism for this horizon of altered shales. Their very great lateral extent and the great uniformity in character point likewise to uniformity in the conditions under which metamorphism operated, and this at once follows from the enormous scale on which the Bushveld Plutonic Series was intruded.

Now immediately below the Magaliesberg Quartzite lies the interesting transition rock, the characters of which are partly and mainly those of the Groothoek type, while mineralogically—especially in the presence of macroscopic andalusite—towards the base of this horizon only, they lean towards the Longsight type. It is difficult to realise that a single intrusive sheet should have produced completely recrystallised cordierite contact fels equal to its own thickness in vertical extent, and it seems more probable that the direct influence of the main body of the Bushveld extended some way down into the Pretoria Series.

North-westwards from the Motse River, as far at least as Chunies Poort, it seems clear that the main agent of metamorphism is the body of the Bushveld Plutonic Series, the thermal effects of which were communicated through some 3,000 feet of the Pretoria Series, certainly to well below the Daspoort Quartzite. The following points may be briefly referred to in support of this view. In the first place the intrusive sheets are very feebly developed and are much reduced both in number and thickness, yet the sedimentary rocks are, if possible, even more strongly altered than in the southern areas. In the second place, as shown above, certain contact minerals—sillimanite and staurolite—are distributed vertically in a manner depending on the distance from the margin of the Plutonic Complex. Numerous instances are known from various parts of the world where, in the contact aureoles round large intrusive masses, such metamorphic minerals characterise certain zones of altered sedimentaries.* The presence of fairly coarse thin aplitic veins interbedded in the mica schists also point to the fact that the rock in contact with them had been elevated to a considerable temperature, for it is not possible to otherwise account for their coarsely crystalline habit. Lastly, the Pretoria Series becomes appreciably thinner when traced from Lydenburg towards Chunies Poort, and if the heat had travelled from the Bushveld Plutonic Series into the Pretoria Series through a vertical range of 3,000 feet, it would be sufficient to account for the presence of the contact phenomena. Below the Timeball Hill Quartzite, the Longsight type prevails solely, and the presence of fairly thick intrusive sheets is capable of accounting for the metamorphism met with. If a difficulty is felt in realising transference of thermal effects over such an, apparently, large distance it should not be forgotten that the 6,000 or 7,000 feet of the entire Pretoria Series becomes quite subordinate, when compared with the dimensions of the central plutonic basin, which covers an area of some 13,000 square miles, and in the eastern Transvaal has a width of over 100 miles.

In M'Phatlele's Location the influence of the intrusive sheets has very probably vanished altogether—if they were at all formed there.

5. *Review of the Metamorphic Phenomena as a whole, and their connection with the Structure.*—The striking characters of the altered rocks of the Pretoria Series as a whole and the evident connection which exists

* G. Barrow, *loc. cit.*, p. 330.

between the Bushveld Plutonic Complex and the geological structure and the distribution of the Transvaal System, present features of more than purely local interest, as they seem to throw some light on certain more general questions, such as the origin of rocks of the crystalline schist type. It is not necessary here to do more than shortly indicate the general bearing of the results, the subject having been treated more fully elsewhere.*

In the first place, taking the whole group of altered rocks from Lydenburg to Chunies Poort, they are essentially of contact-metamorphic origin. This has been clearly brought out, whether they are merely well-bedded shales, with conspicuous new minerals, such as have been embraced under the term Longsight type, or whether their gneissic and schistose characters are strongly marked, as in the Malips River type. The abundance of biotite, cordierite, staurolite, and chiastolite—and in a lesser degree of andalusite, is certainly in general agreement with rocks ascribed to the same agency from many large intrusive bodies all over the world.

The particular feature of great interest is the development of gneissic and schistose structures, which often become so pronounced as to completely transform the otherwise undoubtedly contact-metamorphic rock into one indistinguishable from types, which elsewhere would without hesitation be termed crystalline schists. It is well worth while to consider this aspect a little more closely.

Such rocks are found only in the folded area in the angle of bend between the Drakensberg and Strydpoort Ranges, and continue from that district westwards to Chunies Poort. Field evidence clearly shows that the schistosity is developed gradually in the direction from Lydenburg towards Malips Drift, and becomes more pronounced the nearer one approaches the disturbed region. This suggests a genetic connection between the earth movements and the crystalline schist habit of the altered rocks. There can be little doubt that the abnormal geological structure in the western part of the Haenertsburg Gold-fields was caused by the intrusion of the Bushveld Plutonic Series, and the striking folds show, that the beds have been subjected to great pressures. Therefore, one must conclude that, while the Pretoria Series was under the influence of this intrusion, and consequently was being metamorphosed, the shales and quartzites were also subject to similar pressure. Such conditions would certainly tend to develop phenomena of orientation and mechanical deformation. To prevent the issues from becoming obscured, a sharp distinction must be drawn between schistosity and mechanical deformation. The latter is more pronounced in the quartzites; the former is best shown in the mica-schists, sericite-schists, and gneisses. The various features pointing to mechanical deformation were described above in connection with the Daspoort Quartzite. A rock like this has a composition unsuitable for producing striking contact metamorphic effects, still the presence of tourmaline indicates that it has been subject to them. The prevalence of strain shadows, cataclastic structures, etc., point rather to the conclusion that the rocks were in a more rigid condition, when brought under the influence of pressure. But the case is very different in the case of the schists and gneisses. These show no true mechanical structures, such as the bending of the mica laths, etc., but only orientation and generally pronounced schistosity. They were, moreover, originally thinly bedded shales, readily permeable to hot solutions carrying mineralising agents, the more so as under the influences of folding, etc., their cohesiveness would become reduced. The appearance of the thin sections shows that metamorphism took place, not while they were in a solid or more rigid condition, but rather in a more plastic state and traversed by mineralising solutions. The widespread occurrence of highly characteristic contact metamorphic tourmaline is a strong argument in favour of this.

As the region is undoubtedly one of earth movements, it might be argued that dynamic metamorphism is sufficient to account for the phenomena, independently of the presence of the Bushveld Plutonic Series. This view cannot stand the test of detailed examination, mainly on the following grounds. If the movements producing the folded structure occurred after the intrusion of the central plutonic complex, and were accompanied by a kind of "regional" metamorphism, there is no reason, why the alteration should have only affected the shales and quartzites, and have left the intrusive sheets untouched. These show no signs of metamorphism or directional structures—ortho-gneisses do not occur. Similarly, the various schists and gneisses ought to show mechanical deformation, just as the quartzites do, and the same would be expected in the igneous bands in the mica schists. Such features are, however, not to be found.

It is, therefore, concluded that the schistose rocks in the folded area owe their resemblance to crystalline schists to the fact, that they were metamorphosed while under considerable pressure due to the intrusion of the Bushveld Plutonic Series. The term crystalline schist is commonly understood to mean a rock combining the properties of well marked, oriented divisional planes, and a thoroughly crystalline structure, with a mineralogical composition essentially of a dynamo metamorphic origin, that is due to great pressure. The crystalline schists in the portion of the eastern Transvaal here dealt with answer the above definition only as

* A. L. Hall, *loc. cit.*

far as these structural features are concerned, while the strikingly linear arrangement of certain zones in the norite along the right bank of the Oliphants River probably represent analagous phenomena on a larger scale. It is now generally admitted that where this foliated structure takes place on a smaller scale, the physical laws involved are controlled by the so-called principle of Rieke, first applied to the case of crystalline schists by Becke.* According to this, pressure tends to lower the melting point of a substance, whether its volume is increased or decreased during melting. In the application of this principle to the case of crystalline rocks, it is argued, that where a mineral has surfaces lying against the pressure, it is dissolved away and redeposited along those parallel to the pressure. While this view explains the development of oriented and elongated minerals such as biotite, it does not of course account for the mineralogical composition as a whole.

The latter is controlled by the Law of Volumes, first stated by R. Lepsius†; according to this, the molecules during metamorphism tend to become rearranged in such a way as to assume the smallest volume. The influence of pressure, therefore, is manifested in the endeavour of the material in process of metamorphism to crowd itself into the smallest space. Viewed in this light, the abundance of sillimanite, staurolite, and garnet, the predominance of albite among the felspars, the occurrence of common amphibole and glaucophane, and in a lesser degree of zoisite, is significant—for in most of these the actual molecular volume is less than that represented by the sum of the same quantity for each constituent oxide. At the same time, the presence over the whole metamorphic area of biotite and more variably cordierite, and widespread tourmaline, with occasionally andalusite, shows that essentially the rocks are of contact metamorphic origin throughout. To some extent, even in areas where there is no evidence in the field of any tectonic disturbances, e.g., the Spekboom River valleys, sillimanite, staurolite, and garnet occur, though sparingly.

Therefore both the argument from the foliated character of the intrusive material, and that based upon the somewhat abnormal mineralogical composition—which tends to show the influence of the Law of Volume in the folded region—go to support the conclusion, that the crystalline schists between the M'Thlapitsi River and Chunies Poort are contact metamorphic rocks, which have become schistose owing to metamorphism under greater pressure.

(*c*) *Igneous Rocks intrusive in the Transvaal System.*

In the present portion of the eastern Transvaal, as elsewhere, the Transvaal System contains numerous igneous bodies, especially in the Pretoria Series, which represent intrusive sheets. Their mode of occurrence and distribution is very similar to that shown in the central Transvaal, and the contact alteration seen above and below proves their intrusive relationship in nearly every case. The thickness of each sheet is always greater over the more southerly area. Along the Motse River they become a little reduced in number, and are thinner, while in the western part of the Haenertsburg Gold-fields only a few very thin intrusions are left.

The great majority are found in the Pretoria Series, a few also in the Dolomite. The similarity in composition of those nearer the edge of the Bushveld Plutonic Series to the norite margin of the latter complex, as well as their greater frequency in the upper horizons, suggests a genetic connection.

The rocks throughout are holocrystalline, dark-bluish green, medium to coarse grained types, weathering in the familiar manner described in previous Annual Reports.

Several of these sheets in the upper part of the Pretoria Series belong to rocks allied to diorite. Thus south of the Steelport River, and below the Magaliesberg Quartzite occurs an intrusion, which under the microscope consists almost entirely of green typical hornblende and well twinned plagioclase, together with ilmenite, largely transformed into leucoxene, but still presenting characteristic trigonal outlines. The felspar is an andesine-labradorite.

The sheet underlying the series of staurolite and chiastolite slates along the Motse River and directly above the Timeball Hill Quartzite belongs to the same family, and again consists of amphibole and plagioclase, but the latter occasionally appears in graphic intergrowth with quartz.

Between the Mabola Berg and the farm Pendge and close to the top of the Black Reef Series occurs a sheet intrusive in the Dolomite. The rock is dark bluish and fine grained, owing to the presence of light greenish-white pebbles of plagioclase, resembling saussurite. It has a kind of mottled appearance. In thin section the structure is markedly ophitic, owing to the abundance of granular pyroxene which embraces the felspar. The latter occurs in a few very large cloudy phenocrysts and in numerous lath-shaped crystals. These give an extinction answering to labradorite for sections at right angles to M(010). A little chlorite and

* F. Becke, "Über Mineral Bestand und Struktur der Krystallinen Schiefer."
† R. Lepsius, "Die Geologie von Attika," Berlin 1893.

one irregular mass of a broken secondary mineral resembling serpentine also occur. The rock may be classed as a diabase. Dykes are very rare in the Black Reef Series; several outcrops, viz., near the Mamoutzuri and below the main escarpment in that neighbourhood, again near the old Scandinavian Camp, were found, of a highly decomposed, pale reddish, earthy rock running apparently for some distance across the strike of the Transvaal System. The best case of a dyke was met with in the bed of the Motse River, on its right side, about midway between the Daspoort and Magaliesberg Quartzites on Havercroft (807). This rock forms a straight, very sharply defined, black compact type about 10 feet wide, running roughly east and west. In thin section it consists of an irresolvable, very dark groundmass, in which lie scattered microlites of labradorite, and a few sections of a chloritic mineral. This dyke cuts through the metamorphic slates, and must belong to an age later than that of the intrusive sheets.

(f) Contemporaneous Tuffs and Flows.

The group of rocks classed as contemporaneous occur along one horizon only, which agrees closely with the position of similar outcrops described in the Annual Reports for 1905 and 1906.* In connection with the survey of portions of the Carolina District, Dr. Humphrey found another tuff near Carolina, very closely resembling the northern occurrences and in approximately the same horizon. Altogether there are, therefore, four distinct outcrops of these tuffs.

The most extensive and important evidence of volcanic tuffs was found near the Steelport River on the farms Naboomkopjes (574) and Alverton (888), about 8 miles north-east of the junction from Steelport and Spekboom Rivers. From this neighbourhood the rocks are met with along a continuous band, some 33 miles long and running parallel to the strike of the Pretoria Series. Especially on the left bank of the Steelport River and for some miles north-westwards the tuff gives rise to a line of fairly prominent kopjes. The maximum width of the outcrop is about two miles, while the thickness varies considerably. At Naboomkopjes the tuffs are some 600 feet thick, but further north they thin down rapidly to a thickness of less than 100 feet near the Motse River, while a little south of the junction between the M'Thlapitsi and Oliphants Rivers, they gradually die out (see Map, Plate IX).

These rocks occupy an horizon a little above the Daspoort Quartzite. On the west side of the excellent outcrops on Naboomkopjes, their relationship to the overlying beds is not seen owing to thick accumulations of red sand; on the east side one finds a thin intrusion immediately underlying the tuffs, though good contacts could not be found. This sheet metamorphoses underlying shales into greyish chiastolite slates. The main mass of the tuff forms a very hard compact, bluish green rock, containing numerous foreign fragments. The weathered surface is of a dark coloured, dirty, rusty brown, and shows up strongly the included fragments, sometimes scarcely visible on a fresh fracture. Surfaces long exposed to the influences of weathering develop a peculiar reddish mottled character, not unlike the appearance of troctolite under similar conditions. The included fragments are somewhat rounded and average half an inch in length, but locally pieces 9 x 6 inches are found. The bulk of these are pale greenish, very hard and compact rocks, resembling altered shales, hornfelsic in character, and altered quartzites.

In thin section appearances characteristic of tuffs are found. Odd shaped elongated particles, resembling drawn out vesicles are common. These closely resemble similar ones seen in thin sections cut from the outcrops found previously further south, and which are clearly composed of brownish isotropic glass (see Plate VI, Fig. 5). At Naboomkopjes they appear devitrified. The groundmass throughout seems to have undergone a secondary silification, and such appearances suggest, that the tuff horizon suffered contact-metamorphism like the bulk of the Pretoria Series did in this area. Viewed in the light of what has been stated above regarding the increased intensity of the metamorphism from south-east to north-west, it is probable that south of Lydenburg, where this alteration is feeble, it did not go far enough to destroy the originally glassy portions, but further towards the Motse River it became sufficiently powerful to cause the glass to assume a crystalline structure and silicify the tuff throughout. Hence, one must conclude that the rocks represent an interbedded series of contemporaneous origin of an age earlier than that of the intrusion of the sheets and the formation of the Bushveld Plutonic Series.

In the present area, the peculiar igneous rock met with in the central and western Transvaal, and referred to elsewhere as the "Vesicular diabase," also occurs, and at the identical horizon a short distance below the Daspoort Quartzite. It has been traced from the Delagoa Bay railway northwards along the foot of the Mauch Berg, across the valley of the Ohrigstad River and thence as far as the Motse River, a little east of the confluence of that stream with the Oliphants River, always along the same horizon and easily identifiable

* Annual Reports of Geol. Survey for 1905 and 1906. See also, A. L. Hall, "Note on Contemporaneous Igneous Rocks in the Pretoria Series of the Lydenburg and Rustenburg Districts," Trans. Geol. Soc., S.A., vol. xi, 1908.

by the presence of numerous quartz blebs and vesicles, sometimes drawn out after the manner familiar in lava flows. It was not found to cross over into the Haenertsburg Gold-fields, and probably dies out a little further south of the point, where the Daspoort Quartzite crosses the Oliphants River. The evidence in the Lydenburg District does not show conclusively, that this rock is of the nature of a contemporaneous flow, but recently in the Rustenburg District—as described in another portion of this year's Report—clear proof was found, which leaves little room for doubt, that it is not an intrusive sheet, but a lava of basic affinities.

(*g*) *Rocks of the Bushveld Plutonic Series.*

All the rocks belonging to the Plutonic Complex of the Bushveld examined over the present area are part of the basic margin composed of norite, gabbro, pyroxenites, and hypersthenites, with their variations. They are confined to the western portion of the area, where they form a broad band some 12 miles wide. The whole of the striking range of the Lulu Mountains is composed of very uniform norite, in every respect similar to that in the central and western Transvaal, north of the Magaliesberg. It is interesting to note that in the latter area the width of the norite margin is much less than in Secoecoeniland. Although here the mapping was not carried as far westwards as the crest line of the Lulu Berg, the red granite lies some miles still further. Another difference is shown in the development of foliation, the significance of which was pointed out above in connection with the metamorphism of the Pretoria Series.

Little need be added to the description of the common norite given repeatedly in previous Annual Reports. Its general distribution and mode of weathering, resembling that of granite, has been given above. Considering the norite as a whole, there is very little variation in the great mass of it. The composition of the rocks of which the Lulu Mountains are made is remarkably constant, and is identical with that of the Pyramid Zone north of Pretoria, or south of Bethany in the Rustenburg District. It is a medium or coarse grained, mottled greyish-white rock, composed essentially of rhombic pyroxene and plagioclase, both always very fresh. The former is nearly always pale, slightly pleochroic or non-pleochroic hypersthene or enstatite. Occasionally, one finds more deeply coloured varieties, which are then strongly pleochroic in brownish tints, and belong to the more ferruginous members of the group, viz., bronzite. Measurements made in a large number of plagioclase sections cut from the symmetrical zone give an extinction of about 30 degrees, which indicates labradorite. The structure is hypiodomorphic and may vary much from coarse to granular. East of the foot of the Lulu Range, the norite passes into darker coloured, fine grained rocks, more greenish in colour. This change affects a transition from fine coarse-grey norite to types allied to diabase, but the changes are more structural than mineralogical, since rhombic pyroxene is still abundant. The plagioclase has now lower extinction in symmetrical sections—M(010), while the structure is commonly ophitic. The rock at the beacon on the summit of Maronah Mountain overlooking the valleys of the Spekboom and Steelport Rivers illustrates this. In the field these variations are scarcely pronounced enough to enable a line to be drawn between them. The foliation is confined to the portions nearest the Magaliesberg Quartzite, and is seen in the peculiar arrangement of norite kopjes, sometimes arranged perfectly straight and giving rise to a series of linear ranges. In thin section it can be noticed along the junction with the underlying Pretoria Series, notably in the Schlickmanns Kloof District, by a tendency of the pyroxene to become oriented. Such experiences agree with the observations made elsewhere, as near M'Phatlele's Location,* and must be regarded as due to piezo-crystallisation. On the farm Clapham, this banding is sometimes shown in the hand specimen (984—C2).

It is not necessary here to describe in detail all the numerous variations from the typical norite. They are more or less local, and some appear to follow the distribution of the chromite deposits. In composition there is a great range, the least basic rocks consisting almost entirely of labradorite felspar, while the heavier dark coloured varieties are made up of much hypersthene, enstatite, serpentine and chromite. The latter may pass rapidly into almost pure aggregates of chromite. The first-mentioned rocks are well exposed on the farm Clapham and Forest Hill, and are light coloured, almost white, phases of the noritic magma, thoroughly crystalline and medium grained. In the hand specimen irregular granular patches of a black mineral impart to these a peculiar appearance. The same dark mineral is often found scattered through the mass in isolated minute grains. Where the latter are not confined to certain portions only, the rock assumes a general appearance not unlike some varieties of the older granite. This less basic type is sometimes markedly schistose. Thin sections consist almost entirely of very fresh, more or less oriented labradorite with very little pyroxene in the form of interstitial matter. Similar rocks have been found by the writer in the norite area east of Sterkstroom, in the Rustenburg District, south of Bethany.

The more basic varieties are throughout very poor in plagioclase, distinctly heavier and darker in colour. They are confined to a zone roughly midway between the top of the Magaliesberg Quartzite and the foot of the eastern side of the Lulu Berg. The usual types vary from pale green to black; in the latter

* See H. Kynaston, *loc. cit.*

case chromite is nearly always present in small scattered grains, and wherever that deposit occurs in more concentrated masses the occurrence of black, heavy, lustrous hypersthenite, or enstatic rock in close proximity is usually observed, e.g., on Mooihoek, Jachtlust, etc. The paler varieties are made up almost entirely of light greenish-grey hypersthene and in several sections plagioclase is not represented at all. Pleochroism is very weak, but where observable always gives a pale rose pink tint. The mode of occurrence of the chromite and its relationship to the other constituents is considered below. Commonly these basic varieties assume a granular structure, especially where one approaches a chromite deposit. On the farm Dsjate, near Secoecoeni's old kraal, and close to Wolseley's Fighting Kop, occurs a small mass of very coarse dark diallage rock, containing a little copper. In general appearance this variety differs markedly from the common norite; it also sometimes shows labradorite with a characteristic bluish opalescent sheen in the hand specimen. Besides the last-named mineral, quite subordinate in amount, the thin section shows mainly diallage and hypersthene. The former is full of oriented inclusions and has in consequence a metallic lustre in reflected light; herring-bone structure is well shown under the microscope. On Mooihoek, west of the old Lydenburg main road, occurs a fairly large mass of dark coloured serpentine. The rock is compact and nearly black, while surfaces long exposed to weathering have a dirty brownish appearance, and are pitted in a peculiar manner. In the hand specimens only diallage and a mineral resembling bastite are recognisable; the thin section shows in addition much olivine and serpentine, together with iron ore (derived by decomposition from the olivine) and chromite. Characteristic mesh structure is marked and indicates olivine as the parent mineral of the serpentine.

On the farm Clapham (625), east of the Lulu Berg and a little west of the main road, a narrow dyke was found composed of a dark compact, dark coloured rock, crowded with short and very delicate needle shaped plagioclase. The thin section shows phenocrysts of pyroxene and lath shaped labradorite, while the dark, compact, brown mass is mainly made up of isotropic matter with a later generation of felspar microlites. The dyke cuts across the norite and bears a general resemblance to the one cutting the altered slates of the Motse River. Probably both belong to the same period. The one on Clapham may be classed provisionally as a basalt.

5. Economic Geology.

On the whole, the area under review is not of first rate importance economically, though it seems indicated that more vigorous prospecting in certain areas would be rewarded with success, for a considerable portion of the district is quite unknown and does not appear to have been prospected at all. It will be convenient to consider first the Haenertsburg Gold-fields.

(*a*) *Haenertsburg Gold-fields.*

This district stretches from the escarpments of the Haenertsburg and Strydpoort Ranges westwards and southwards as far as the Oliphants River, and extends from the junction of that stream with the Steelport River, north-westwards as far as the Malips River. It is almost entirely made up of the Black Reef Series and the Dolomite. Between Malips Drift and the Motse River, the lower portion of the Pretoria Series is included. The country throughout is extremely wild and rugged, so that attempts at development have to meet with great transport difficulties. Mining or other economic work has been carried on principally at the following localities:—The Woodbush Mine, situated in the granitic area south of Haenertsburg; the Pennefather and "New Found Out" Mines, working in the Black Reef Series. Lastly there are the alluvial workings on the Wolkberg. A description of the above is contained in Mr. Mellor's Report.* At the time of the writer's visit, work on the "New Found Out" Mine was suspended.

In the western portion of the Haenertsburg Gold-fields between the M'Thlapitsi and Malips Rivers, very little prospecting appears to have been done. Near the base of the Pretoria Series, in the lower part of the thick series of ferruginous slaty quartzites, as well as in the inter-bedded band of the same rock in the Dolomite, blue crocidolite occurs in considerable quantity, viz., on Lot 263. It is found in thin veins inter-bedded with the shaly quartzites and varying from half an inch down to mere films. Such veins are often crowded together in the hand specimen and when fresh, consist of soft, pale blue, silky fibrous crocidolite. Certain varieties of the mineral are brownish yellow in colour and approach "Tiger's Eye" in appearance, but are not suited for the production of asbestos fibre. Though the veins of the blue asbestos rarely exceed half an inch in width, they are very abundant along the southern edge of the Haenertsburg Gold-fields, between the Malips and M'Thlapitsi Rivers. The bulk of the fibre in the important Canadian deposits, moreover, is not more than half an inch wide.† In the blow-pipe the mineral only becomes slightly fused, but it must be borne in mind, that the specimens were necessarily collected from outcrops long exposed to weathering.

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* Annual Report Geol. Survey, 1906, p. 42, etc.

† F. Cirkel, "Asbestos, its Occurrence, Exploitation, and Uses," Mines Branch, Department of Interior, Ottawa, 1905.

Regarding that portion of the Haenertsburg Gold-fields lying between the Oliphants River and Drakensberg, which is marked in Jeppe's map as "Unsurveyed Government Land," no information could be obtained locally of any prospecting work ever having been done here. It is an extremely mountainous and difficult country to examine; there are no roads whatever, and it can be crossed on horseback along certain Kaffir paths only. Excepting in the immediate neighbourhood of the Mamoutzuri there are no white homesteads, and native habitations are few and far between. The Transvaal System is exposed all over this strip of country in a superb manner, and it seems that the base of the Pretoria Series, as well as the upper portion of the Dolomite, deserves some attention from the prospector. The detailed stratigraphy of the three gold-bearing reefs in the Lydenburg District, as exhibited in the Pilgrims Rest area, have been discussed in detail in the Annual Report for 1906,* and it has been shown that the presence of a characteristic conglomerate always indicates the horizon of Bevets Reef. From the position of this conglomerate, the approximate horizon of the Theta and Beta Reefs can thus be roughly deduced. A rock resembling the Bevets Reef was met with in the area a little upstream from the junction of the Oliphants and Steelport Rivers along the latter. The limitation of the area, which it might be worth while for the prospector to examine, is rendered less difficult by the constant presence of an intrusion sheet at the base of the Pretoria Series. Where this line cuts across the Oliphants River, it enters the unsurveyed portion of the Government ground forming part of the Haenertsburg Gold-fields. In applying the experience obtained at Pilgrims Rest to the same formations further north, due allowance must be made for the gradual increase in thickness of the Dolomite as a whole, but some idea of the gradual change in horizon is afforded by the position of the Elandsfontein Reefs, mentioned in the last Annual Report.

Asbestos resembling some varieties of the mineral as found east of the Malips River is also to be met with in the unsurveyed portion of the Haenertsburg Gold-fields and the ground immediately adjoining it along the right bank of the Oliphants River. Thus on Pendge (780) are found several veins of dirty yellowish asbestos of considerable thickness. One occurrence showed veins 6½ inches wide, but the fibres do not well withstand heat. It is quite possible, however, that deeper down the quality may improve, as the material examined had been left exposed for a long time.

(*b*) *Secoecoeniland.*

The portion lying between the crest line of the Lulu Mountains and the top of the Pretoria Series belongs to the eastern part of Secoecoeniland and has certain advantages over the district discussed above. It is much less broken and more readily accessible, being served by a fairly good main road connecting Lydenburg and Pietersburg, so that economic development is not handicapped as regards transport to the same extent as further east or north. Chromite and copper are the main economic products, and especially the former is of importance, as a considerable quantity has already been located;† ores of copper occur only in the norite, as on Dsjarte and elsewhere along the Lulu Range, or as on Derde Gelid, in the basic rocks included between the subsidiary quartzites of the Magaliesberg horizon. They are associated with ilmenite and other minerals, but do not possess great economic value.

The chromite deposits are more numerous and extensive; they occur along a more or less well-defined horizon in the norite, and extend from near the junction of the Malips and Oliphants Rivers south-eastwards for many miles—at least as far as the Steelport River. Chromite occurs on the following farms:—Jachtlust (333), Winterveld (690), Brakfontein (84), Moeilijk (605), Twifelaar (72), Mooihoek (147), and Hendriksplaats (636). These occurrences form a connected set of outcrops running approximately parallel with the strike of the Pretoria Series, and at an average distance of three miles from the uppermost quartzite. The location of the chromite reefs is much facilitated, because the country rock in which they are found is not the typical grey norite, but belongs to the pyroxenite and hypersthenite or enstatite varieties. In almost every case one finds highly characteristic, heavy black lustrous hypersthenite or enstatite rock in close proximity to the reefs. The mode of occurrence and relationship of the latter are the same throughout the district, and the description here given of the well-exposed bodies on Mooihoek are typical. In the best outcrop about 1½ miles west of Mr. Ward's store, at least three separate reefs have been exposed in the same cutting; these are well bedded, with a common south-westerly dip of a few degrees. Fig. 1 represents them drawn to scale. At first sight there is apparently a very sharp junction between the ore and the country rock, but careful examination shows a rapid transition, caused by the concentration of the chromite grains. Nearer the centre of each reef the chromite is quite pure. The country rock separating the reefs is a dark greenish,

* Annual Report of Geol. Survey for 1906, p. 93.

† Compare A. L. Hall and W. S. Humphrey, "On the Occurrence of Chromite Deposits along the Southern and Eastern Margin of Bushveld Plutonic Complex," Trans. Geol. Soc., S.A., vol. xi, 1908.

granular hypersthenite. From the point shown in the figure, the ore can easily be traced along the surface both northwards and southwards, and is invariably associated with deep black lustrous basic phases of the norite series.

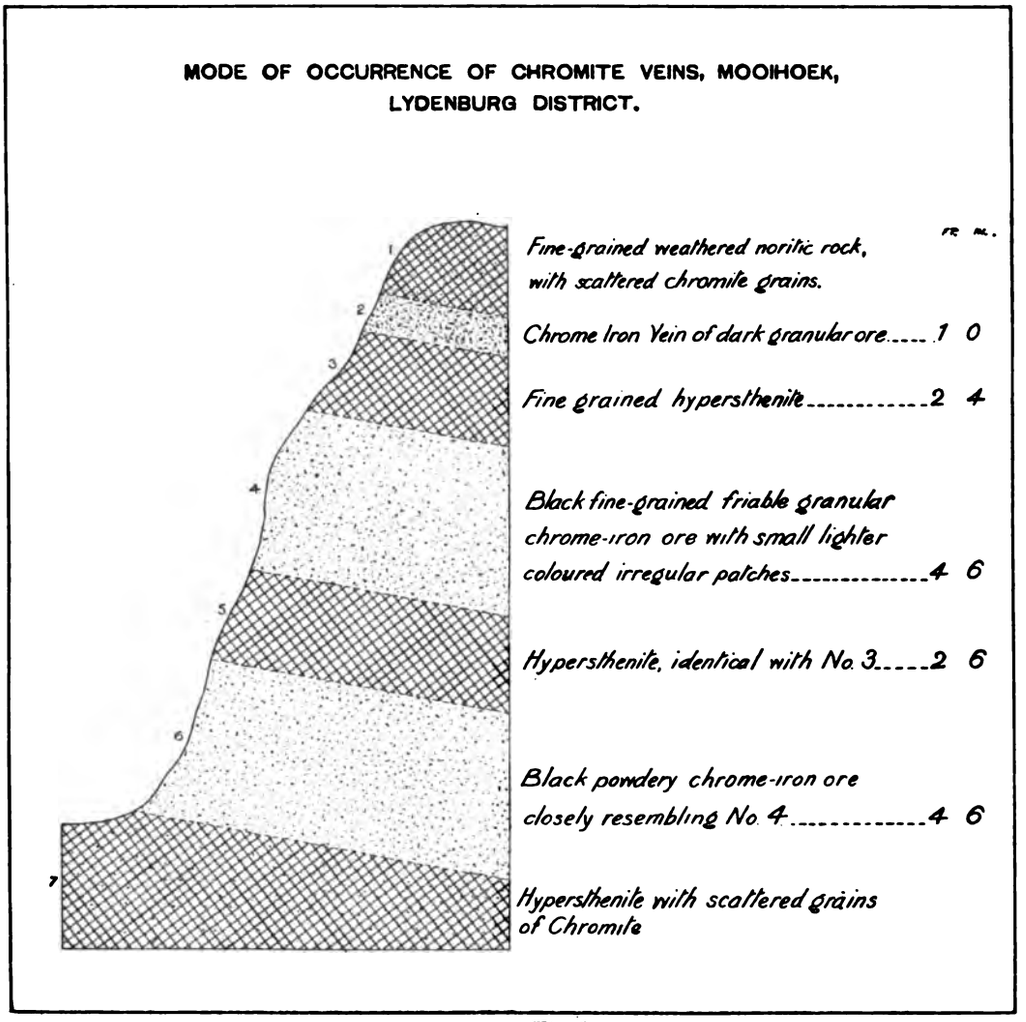
MODE OF OCCURRENCE OF CHROMITE VEINS, MOOIHOEK, LYDENBURG DISTRICT.
Ft. In.
Fine-grained weathered noritic rock, with scattered chromite grains.
Chrome Iron Vein of dark granular ore..... 1 0
Fine grained hypersthenite..... 2 4
Black fine-grained friable granular chrome-iron ore with small lighter coloured irregular patches..... 4 6
Hypersthenite, identical with No. 3..... 2 6
Black powdery chrome-iron ore closely resembling No. 4..... 4 6
Hypersthenite with scattered grains of Chromite
1
2
3
4
5
6
7

Fig. 1

For the following analysis of the ore from the outcrops shown in Fig. 1, the writer is indebted to **Mr.** T. H. B. Wayne, A.O.S.M., Durban :—

Moisture and combined water	12·10 per cent.
Silica	4·40 ,,
Chromic oxide	51·29 ,,
Ferrous oxide	23·33 ,,
Alumina	2·40 ,,
Lime	1·12 ,,
Magnesia	4·32 ,,
Phosphorus	mere trace.
Manganese oxide	0·60 per cent.
Cobalt and nickel oxides	0·40 ,,
Sulphur	mere trace.
	99·96 per cent.
Platinum	Nil.

Compared with the numerous other occurrences, both in the eastern and central Transvaal, which rarely show more than 40 per cent. of Cr_2O_3, the above analysis represents a valuable deposit.

Another occurrence near the northern fence of Mooihoek shows a thin reef identical in character with that first mentioned, and associated with the same kind of hypersthenite. Its position agrees with the average strike of the more southerly outcrop. There is little doubt that more careful prospecting would yield further finds between Mooihoek and the occurrences near Jachtlust. On Hendriksplaats the chromite is veined by a leech green compact mineral; this is chrome garnet (uvarovite). The ore is usually pale black in colour and finely granular. Wherever it is well exposed it has become more friable, and may assume a greenish tint; the latter effect is probably due to weathering, for in thin section each chromite grain is seen to be surrounded by a thin pale green ring, probably representing hydrated chromite. An examination of the reef at Jachtlust showed 40 per cent. of the sesqui-oxide of chromium. In the latter locality are several distinct and well-bedded ore bodies in every respect similar to those from Mooihoek. The presence of rock rich in olivine and serpentine accounts for the occasional occurrence of magnesite; some of these, viz., on Jachtlust, seem to occur in rather large quantities.

Conclusion.—From what has been said above, it appears that the economic possibilities of this portion of the eastern Transvaal are such as to encourage efforts on a small scale. The formations likely to be mineralised are all well exposed, and the presence or absence of payable ore bodies could probably be decided without very great expenditure. The unsurveyed portion of the Haenertsburg Gold-fields, so far as the upper part of the Dolomite and the Pretoria Series below the Timeball Hill Quartzite are concerned, are apparently quite unknown, and it is possible, that prospecting in this region might meet with success.

IV.

ON THE SOUTH-WESTERN PORTION OF THE RUSTENBURG DISTRICT, BETWEEN TAFELKOP AND RUSTENBURG.

By A. L. HALL (*Geologist*).

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IV.—ON THE SOUTH-WESTERN PORTION OF THE RUSTENBURG DISTRICT, BETWEEN TAFELKOP AND RUSTENBURG.

By A. L. Hall (*Geologist*).

1. Introduction.

The present report deals with that portion of the Rustenburg District, which lies to the south-west of the Magaliesberg Range, and west of a line drawn north and south through Oliphants Nek; in the direction towards Zeerust, the area is limited by a line drawn north and south through Tafelkop, while its northern boundary coincides with the Zeerust-Rustenburg main road leading over Magatos Nek. A small strip of countrg about three miles in width belongs to the northern portion of the Potchefstroom District. The map illustratiny the present report is covered by Sheet No. 4 (Rustenburg), which is issued as a separate publication.

The total area examined amounts to 864 square miles, over which 710 miles of boundary lines were traced, and includes the gold-bearing district of Blauwbank, west-north-west of Krugersdorp, described in a separate report.

2. Physical Features.

(*a*) *Topography.*

The southern portion of the Rustenburg District, as far as the present area is concerned, belongs to the High and Middle Veld types of country, the division between which is somewhat sharply defined by the Daspoort Quartzite. Since the inclination of the Pretoria Series becomes gradually less in a south-westerly direction, any dip-slopes present in that formation become more marked as one descends in the series, while at the same time there is a general decrease of dip for the same bed in a direction from east to west. In conformity with this experience the Daspoort Quartzite forms a well-marked dip-slope, which becomes increasingly wider in the Zeerust direction, and effects a well-marked transition between the two types of scenery.

South and south-west of this quartzite, the country presents typical High Veld scenery, almost bare of vegetation and forming a rather monotonous gently undulating table-land, with an average elevation of about 5,000 feet. North of the quartzite the country is distinctly lower, much better wooded, and broken up by numerous hills. The only conspicuous and consistent topographical feature is that due to the Magaliesberg Quartzite, which forms a pronounced escarpment facing the south-west. Since naturally the harder beds tend to stand out as a result of prolonged erosion, the lines of higher ground are confined to the quartzites and the intensely altered shales, wherever the latter have been converted into compact contact fels. The latter type is very prevalent between the uppermost and middle quartzites, and hence the very broken and hilly nature of the Middle Veld portion is easily accounted for.

Perhaps the most striking feature is that due to the Daspoort Quartzite. Since the whole of the Pretoria Series has been thrown into a well-marked strike-fold, and forms a wide semi-circle concave towards Rustenburg, the quartzite stands out like an amphitheatre of high ground, known locally as the Witwatersberg. Unlike the behaviour of the same formation further east, it forms scarcely any escarpment, but is merged insensibly into the south-westerly High Veld plateau.

The only other remaining feature is due to the Timeball Hill Quartzite, which has a low dip of about 6 degrees and hence gives a very wide and uniform dip slope, while its escarpment is quite inconspicuous and hardly noticeable from any distance, excepting where, as near Tafelkop and Coetze Kop, erosion has been rather more effective.

(*b*) *Water-supply.*

Just as the Daspoort Quartzite marks a sharp distinction between the High Veld and Middle Veld, so it divides the area into a well-watered and a poorly watered portion. Towards the south-west below the quartzite, the High Veld country has a poor water-supply; very few of the drainage lines carry permanently

running water, and the local demand has frequently to be met by boring. Even the Elands River, which has the largest catchment area of all the streams flowing northwards from the high plateau, has practically no supply until it begins to descend towards the lower lying ground. The only water-bearing stratum in the whole district is the Daspoort Quartzite. This affords a very good and constant supply, the majority of the rivers issuing from its dip-slope; the Koster River, for instance, rising south of the farm Steinbokfontein, carries an abundant and permanent supply. Hence one finds that practically all the farms, situated on or near the dip-slope of the Witwatersberg, possess a fine water-supply and good agricultural ground.

A rather remarkable feature in the hydrographical conditions is the presence of certain springs high up on the escarpment of the Magaliesberg Quartzite. Perennial springs issue immediately below the main and most conspicuous quartzite krans on the farms Buffelshoek (10) and Magatoshoek (282). Their occurrence is no doubt due to a thin band of shaly rocks, which underlies that quartzite and furnishes a convenient plane, along which the water falling on the overlying catchment area can be accumulated. Similar conditions were noticed in connection with the Daspoort Quartzite in the Lydenburg District.* Rivers, such as the Selons River, which rise and continue to flow between the Daspoort and Magaliesberg Quartzites have a very poor water-supply and, except during heavy rainfall, consist in reality of a series of separate pools. What little water is contained in them is probably due to the presence of the springs associated with the base of the Magaliesberg Quartzite. This is one reason, why the country lying between the two quartzites is so poor in agricultural ground.

The High Veld portion, consisting of a gently undulating and badly watered table-land, is characterised by very wide open valleys, shaped somewhat like a saucer, while the Middle Veld portion contains numerous narrow valleys, especially near the upper boundary of the Daspoort Quartzite—e.g. on Naauwkloof (499) and Hartebeestefontein (514). In a few isolated cases, as a little north of Koster Siding, and on the farm Otterfontein (630), the head waters of the main drainage lines have cut their way backwards through the base of the Daspoort Quartzite, with the result that short gorge-like valleys have been produced near this horizon.

3. The Geological Structure.

The present portion of the Rustenburg District is remarkable for its geological structure, because in this part of the central Transvaal the effects of the change in strike of the Pretoria Series are more pronounced than anywhere else west of the Capital. Near Pretoria the Transvaal System strikes almost due east and west, and continues along the same direction for about sixty miles as far as the neighbourhood of Oliphants Nek. From this point westwards the strike of the Pretoria Series changes rapidly, but without a permanent break, to a north-westerly direction, describing a wide curve concave towards Rustenburg. Near the main road connecting this town with Zeerust, the strike is north and south for a short distance; it then undergoes a second and similar change of strike, but in this case describing a curve convex towards the Bushveld. Thus the strike between Oliphants Nek and Zwartruggen describes a rather sharp S-shaped fold, the effects of which are best seen in the outcrop of the Magaliesberg Range, the quartzite of this horizon being itself thrown into a series of minor anticlines and synclines. Such a decided change in structure must undoubtedly have been accompanied by considerable pressure; one evidence for which is found in the presence of the long and powerful fault† running in a south-easterly direction from near Rustenburg through the whole thickness of the Pretoria Series into the upper portion of the Dolomite, in consequence of which the beds are broken through and not only displaced laterally, but bent round against the fault plane. It is probable that the compression occurred in an east and west direction. The pronounced metamorphic character of the shales, which between the Magaliesberg and the Daspoort Quartzites are intensely altered throughout their entire thickness, also points to the operation of considerable pressure, for although this metamorphism is essentially a thermal one, it presents certain features, which tend to show that contact alteration alone is insufficient to account for the phenomena, and that to some extent dynamic metamorphism has operated concurrently. This aspect of the question is discussed in more detail below.

4. Transvaal System.

(a) General.

All the sedimentary rocks occurring in the area mapped belong to the *Pretoria Series* or Upper division of the Transvaal System, and make up a conformable sequence of beds dipping uniformly to the north, north-east, and east with a dip varying from 3 to 20 degrees. Locally near folds or faults the dip may become very much higher over short distances. Towards the south and south-west, the dip becomes steadily less as

* See Annual Report of Geol. Survey for 1905, p. 43.
† See Annual Report of Geol. Survey for 1906, p. 122.

one descends in the series—thus the average near the horizon of the Timeball Hill Quartzite is only about 5 or 6 degrees. In conformity with this the outcrop of the Pretoria Series increases considerably in width, more especially at the point where the angle of bend in the strike is sharpest. Not only does the dip decrease as one descends towards the Dolomite, but there is also a general decrease in the inclination of one and the same bed in the direction from east to west. The much greater areal extent of the Pretoria Series as one approaches the Zeerust District is further accounted for by the increased thickness. Thus south-west of Rustenburg, the series is about 13,500 feet in thickness compared with 9,000 feet near the Capital.

Associated with the quartzites and shales are a large number of intrusive sheets and two or three dykes, the latter belonging to elaeolite-syenite group, and no doubt genetically connected with certain later phases of the Bushveld Plutonic Complex. The intrusive nature of the great majority of the sheets can be readily proved by the kind of metamorphism produced on the shales in which they occur. True volcanic tuffs, such as one finds along a certain horizon in Secoecoeniland* were not met with, but evidence was available to show, that the thickest of the igneous sheets is probably a contemporaneous flow.

In most respects the general characters of the sedimentary rocks of the Pretoria Series are quite similar to those already described from the country lying further east.† In the present report, therefore, special features only need be alluded to, while the remarkable contact alteration of the shales, which has not so far been noticed in the Pretoria Series of the central Transvaal, will be fully described.

(*b*) *Quartzites.*

The three quartzites, which constitute the most constant and conspicuous feature of the Pretoria Series, wherever it has so far been examined, are also present in the area now under review.

The Magaliesberg Quartzite is the most important, the uppermost, and the thickest of the three. From Oliphants Nek north-westwards it is thrown into several folds, thus frequently possessing a considerable surface width. These features have an important bearing on the local water-supply, for the quartzite is underlain by an impervious bed of shales. To the south and south-west it presents a bold escarpment, which can only be crossed at a few points, e.g. Magatos Nek and Oliphants Nek. Sometimes the base of the quartzite is marked by small but constant springs, alluded to above. Further details regarding the formation are given in Dr. Humphrey's Report on the area surrounding Rustenburg (see p. 84).

The Daspoort or *Middle Quartzite*, giving rise to the feature locally known as the Witwatersberg, is very similar to that of the type section west of Pretoria, and consists of a single bed of medium grained, light coloured, quartzite, with an average dip of 5 degrees and a thickness of about 80 feet. Some six miles north-west of Boons Siding on the Krugersdorp-Zeerust Railway, this horizon is represented for a distance of 3½ miles by two distinct quartzites separated by a thin intrusive sheet. The appearance at first sight suggests duplication due to faulting, but neither above nor below are there any signs of displacement in the associated beds, and it is more probable that the igneous rock has broken through the quartzite, thus causing a discontinuity and producing locally two distinct bands, which must be continuous with one another elsewhere.

In the neighbourhood of Boons Siding, the Daspoort Quartzite still gives rise to a slight escarpment facing southwards, but in a north-westerly direction the feature dies out and the formation appears merely as a continuous tract of elevated ground, slightly higher than the average level of the High Veld plateau, to which it forms the north-eastern boundary.

The *lowermost quartzite* is that of the *Timeball Hill* horizon, and consists in reality of a series of thin quartzites separated by typical unaltered shales. The former are generally only a few feet in thickness, but near the base of the series they tend to become thicker. On the Rustenburg Sheet no attempt has been made to map out these individual quartzites, and the lower have been grouped together into one horizon. The dip of these beds is always very low, usually not exceeding 6 degrees, and consequently one always finds an extensive dip-slope, especially on the farms Rhenosterfontein (71), Panfontein (424), Rietfontein (720), and Vlakfontein (892), near the northern limit of the Potchefstroom District. Tafelkop, situated about nine miles south-west of Koster Siding, forms the only prominent topographical feature due to this series of quartzites. Viewed from points on the old Jameson Road (connecting Krugersdorp with Koster Siding), Tafelkop is noticeable as a long gentle ridge; towards the south-west it has a slight but distinct escarpment, the summit of which is about 100 feet above the general level of the surrounding country. Coetze Kop, south of Boons Siding, is a similar, though less pronounced, feature along the same escarpment. The Timeball Hill Quartzites differ from the Middle and Upper quartzites by being throughout much redder in colour; the distinctive magnetic character of certain beds is also noticeable in this district.

* See Annual Report for 1906.

† See Annual Reports for 1906, p. 119; also for year 1905, p. 65.

(*c*) *Shales, etc.*

The typical well-known shales of the Pretoria Series, which are so extensively developed near the Capital, are not met with in the present area until one has descended to a horizon about midway between the Daspoort and Timeball Hill Quartzites. Above this horizon the majority of the shales are completely metamorphosed into hard, almost compact, thoroughly crystalline contact-fels. Immediately above the Middle quartzites the alteration is less intense, and hence one finds chiastolite slates as the predominating type. Just below the same quartzite occurs the well-known thin band of arenaceous shale or greywacke; this also is distinctly altered.

Unaltered shales are confined to that portion of the Pretoria Series which lies below the base of the so-called "Vesicular Diabase." Here these rocks are very common and cover considerable areas of the High Veld portion between Tafelkop and Boons Siding. They are mainly soft, thinly bedded rocks, light purple to bluish grey, often slightly variegated, and with little or no alteration, except along the contact with a few thin intrusive sheets. The beds associated with the alluvial gold workings north-west of Krugersdorp are often reddish purple in colour and minutely folded over considerable distances.

Another very thick development of typical shales is found underlying the Timeball Hill Quartzites; the rocks of this horizon are in every respect similar to those south of Pretoria. The principal difference between the shale horizons in this district and those further east is that, in the former, one finds deposits of auriferous quartz. The economic features in this connection are treated in pages 75 to 78 of this Report.

(*d*) *Metamorphosed Shales.*

A considerable proportion of this part of the Rustenburg District is occupied by more or less strongly metamorphosed shales and greywackes. Almost the entire thickness of shales, for instance, between the Magaliesberg and Daspoort Quartzites consists of crystalline hornfels, and only immediately above the latter horizon are rocks found which, though obviously altered, still show a shaly character in the hand specimens. The series of altered rocks has a more than merely petrographical interest, on account of the extremely close analogy between them and similar rocks in the Lydenburg District, south of Haenertsburg, which are discussed in another portion of this volume (see pp. 43 to 54).

Then, again, the contact metamorphic phenomena, as a whole, seem to indicate an intimate connection with the geological structure, and therefore with the intrusion of the Bushveld Plutonic Series. For these reasons the subject is considered in greater detail.

From the base of the Magaliesberg Quartzite down to the top of the so-called "Vesicular Diabase" true unaltered shales, like those seen in the type section west of Pretoria, are not found. The abovementioned lower limit lies a little way below the Daspoort Quartzite, and it may be anticipated here, that this igneous sheet is really a contemporaneous flow and has had no share in inducing the metamorphism. Between these horizons the bulk of the sedimentary rocks are made up of crystalline metamorphic types, which differ fundamentally both in their petrographical characters as well as in their topographical behaviour from the unaltered shales further east.

The intense metamorphism of the shales of the Pretoria Series in certain parts of the Colony and the great lateral extent of various well-marked contact rocks were first observed and described by the writer in connection with the survey of the eastern part of Secoecoeniland. It was here found that all the different varieties of altered shales fall naturally into three groups, more or less distinctive both in petrographical characters as well as in their areal distribution.* Since the later experience in the Rustenburg District points to strictly analogous phenomena, it is convenient to adopt the same groups here also, the more so as they are of great practical use in the field and based on genetic principles. Hence the following three classes of metamorphic rocks are recognisable :—

I. Groothoek Type.
II. Longsight Type.
III. Malips River Type.

I. *Groothoek Type.*—Under this term are comprised those metamorphosed shales which are characterised by a fine-grained crystalline structure, in consequence of which all indications of their original nature are lost in the hand specimens. In the great majority of cases the agent of metamorphism is the margin of the Bushveld Plutonic Series, so that the upper horizons of the Pretoria Series contain almost exclusively this class of alteration product. Where any shales occur above the Magaliesberg Quartzite, they are in direct contact with the margin of the body of the Bushveld Plutonic Complex, and consequently all the altered rocks belong

* See A. L. Hall, "On Contact-Metamorphism in the Pretoria Series of the Lydenburg and Zoutpansberg Districts," Trans. Geol. Soc., S.A., vol. xi, 1908.

to this one type. Its petrographical character and mineralogical composition agree roughly with the so-called hornfels rock, but it must be pointed out, that the present rocks are holocrystalline and have no horny appearance; hence the name hornfels is unsuitable, and the designation cordierite contact-fels by Salomon* is considered more appropriate, for it indicates the mode of origin. The altered shales above the Magaliesberg Quartzite have been found along the Sterkstroom, and are referred to by Dr. Humphrey in the present Report. They are indistinguishable from analogous occurrences in Secoecoeniland along the same horizon.

The distinctive characters of the Groothoek type as developed below the Magaliesberg Quartzite can be well studied near the main road leading south-westwards from Oliphants Nek. Reference to the map published as Sheet No. 4 shows the presence of at least seven intrusive sheets between the upper and middle quartzites; the beds lying between these igneous intrusions consist of the same type of highly altered shales, presenting perfectly uniform characters at least as far below the Magaliesberg Quartzite as the south-western boundary line of Rooikloof (212). It is, therefore, clear that the entire thickness of the metamorphosed rocks amounts to many times that of the intrusive sheets, and consequently there can be little doubt that the latter are not the direct agents of metamorphism, but that the phenomena must be ascribed to the vastly greater main body of the Bushveld Plutonic Complex, a conclusion to be discussed more fully below.

The most striking feature of the Groothoek type is the extraordinary uniform characters it presents over wide areas, and specimens collected at the extreme limits of the area dealt with—some twenty miles apart—cannot be distinguished from one another. The rocks consist of dark greyish fine-grained to nearly compact varieties, invariably holocrystalline, and showing a strikingly glittering appearance owing to the abundance of minute dark flakes of biotite. This is also the only mineral recognisable with the naked eye. Hence at first sight the rock might well be mistaken for a close-grained igneous rock. It is also fairly hard and often weathers less easily than the associated intrusive rocks, so that it tends to stand out along irregular lines of higher ground. Prolonged erosion produces large, somewhat thin slabs, which emit a characteristic metallic sound when struck with a hammer. Its sedimentary origin can be recognised in the field only by the bedding, which is, of course, always in conformity with the general geological structure. The texture is throughout granular and fine grained, but a comparison of a large number of hand specimens collected from many different localities shows slight variations in the degree of fineness. Under the microscope no trace of the original bedding planes can be detected.

Thin sections cut from a number of occurrences along the Hex River Section, south-west of Oliphants Nek, and along the Zeerust main road west of Magatos Nek, show the following minerals in approximate order of abundance:—Biotite, cordierite, muscovite, quartz, felspar, tourmaline, sillimanite, and amphibole. This combination clearly indicates a rock of contact-metamorphic origin; also the great prevalence of pavement structure in the groundmass and sieve structure in the cordierite, and to some extent in the biotite, when these are developed in larger crystals, point to the same origin. Biotite is at once the most abundant and most striking constituent, sometimes making up half the section and always of deep brown colour, intensely pleochroic habit, and in short lath-shaped crystals. Cordierite occurs less plentifully and is liable to be overlooked, owing to its badly developed outlines and low refractive index. Its biaxial character, occasional twinning, and numerous inclusions, well seen under crossed nicols, serve to identify it. Where it is highly crowded with inclusions, these are mainly biotite and quartz, and thus produce the peculiar kind of worm-eaten appearance known as sieve structure. Occasionally this may go so far that the mineral no longer appears as one individual, but rather like a collection of granular particles, which are, however, still seen to be genetically connected by exhibiting optical continuity. The mica seems to be the first contact mineral produced, for it appears as enclosures in the cordierite, and sometimes the latter occurs abundantly in larger crystals, making up the bulk of the section, when numerous small mica laths are arranged round the boundaries of the cordierite. This particular feature seems confined to localities further removed from the Magaliesberg Quartzite. The colourless portions of the slide are resolved by crossed nicols into an even-grained, finely granular aggregate of quartz and felspar, representing, no doubt, the felspathic portion of the unaltered shale. Of particular importance is the widespread occurrence of tourmaline, though this constituent is always present in small amounts only. In colour it is deep brown, with a slight tendency to green, and forms small rounded grains or short stout prisms; for these reasons it is very easily missed. When the grains show little pleochroism and are bounded by faces agreeing with the requirements of rhombohedral symmetry, uniaxial figures are observable; when the mineral appears in prism, the peculiar scheme of absorption serves as an additional diagnostic property. Hence the recognition of the tourmaline offers no particular obstacles. The constant presence of the mineral is one of the best proofs for the metamorphic origin of the Groothoek type, and its considerable vertical extent also shows that the influence of the main mass of the Bushveld Plutonic Series must have extended some way down into the Pretoria Series.

* W. Salomon, "Geol. und Petrog. Studien am Monte Aviolo im italienischen Anteil der Adamellogruppe." Z. d. D. Geol. Ges., 1890.

The occurrence in the Groothoek type of ferro-magnesian minerals, other than mica, deserves special mention. It is only noticeable along the contact with the intrusive sheets and confined to a zone a few yards wide. Very good instances are found on Rooikloof along the intrusion crossing the farm a little south of the centre. Here, about two or three hundred yards west of the main road, and close to the first homestead south of the main drift across the Hex River, the junction between the igneous rocks and the overlying Groothoek type can be fixed to within about two feet. The altered sedimentary nearest the intrusion is a dirty dark greenish, almost compact rock, consisting of a finely granular type, in which amphibole forms almost the entire mass; yet a few yards into the overlying altered shale common cordierite contact-fels prevails, with biotite as the only ferro-magnesian mineral. The former variety may be designated amphibole-hornfels, and its abnormal mineralogical composition and local restriction to the immediate line of contact clearly indicate a directly metamorphic influence of the underlying intrusive rock, resulting in the transference of basic material. Such an experience agrees closely with the occurrence of pyroxene-hornfels along the contact line between the margin of the Bushveld Plutonic Series and the overlying shales in the Schlickmanns Kloof district, north of Fort Burger in Secoecoeniland* (see Plate IX).

II. *Longsight Type.*—When the metamorphosed shales are altered in a lesser degree, so as to clearly show their original nature in the hand specimen, and at the same time generally contain contact minerals visible to the naked eye, they form a group of rocks quite distinct structurally, as well as mineralogically, from the preceding type. Such varieties constitute the Longsight type, a name chosen after the locality north-west of Ohrigstad, where this form was first met with in characteristic development.*

In the present portion of the Rustenburg District this type is confined to horizons close to, and both above as well as below, the Daspoort Quartzite. Thus nearly all the shales seen along the Hex River section, from the north-eastern boundary of Middelfontein (662) to the top of the Daspoort Quartzite, and along the Zeerust main road from Selons River to the south-western corner of Rietfontein (299), consist of dark greyish blue to almost black slaty rocks, containing conspicuous macroscopic needles of chiastolite, less frequently andalusite, while biotite is quite subordinate. Locally, e.g. near the centre of Middelfontein (662), graphite is abundant, and hence the rocks are soft and black. In nearly every case the metamorphism is distinctly less intense than that of the former type, so that the true shaly nature of the rock is at once evident. Immediately below the Daspoort Quartzite occurs a band of sedimentary rocks approaching a sandy shale in character, and this horizon represents the vertical limit of the metamorphic phenomena in this part of the western Transvaal. Below the great sheet of igneous rock underlying this greywacke, and running along the right bank of the Elands River, the shales are lighter coloured and practically unaltered.

Chiastolite, andalusite, and biotite are the most important contact minerals; especially the first two are often very conspicuous, and chiastolite may occur in needles an inch in length; when in thin section it shows the familiar oriented graphitic inclusions like those found in the Longsight type of the eastern Transvaal (see Plate V). The groundmass is much less recrystallised than in the Groothoek type. The graphitic shales of Middelfontein contain chiastolite, but not as a rule visible in the hand specimen; in thin section the presence of this mineral is often only recognisable under crossed nicols by the optical continuity of portions of the apparently uniform groundmass, which possess crystal outlines, since the chiastolite individuals are practically rendered opaque by the abundance of graphitic matter not yet distributed in the fashion peculiar to more highly crystalline varieties of this mineral.

It is sometimes found that in the immediate vicinity of the upper or lower contact with any one intrusive sheet—and under those conditions only—the Longsight type passes rapidly into a true hornfels. Along the south side of the main Zeerust road and a few hundred yards west of the Koster River Drift, on the farm Rietfontein (299), such variations consist of very compact, dull, and hard pale bluish rock, possessing a kind of horny appearance. In such cases, therefore, the designation hornfels seems justifiable. Under the microscope these varieties show a very fine-grained and thoroughly fresh completely re-crystallised quartz felspar mosaic without any contact minerals. The point is of some importance, for it seems to suggest the probability that the Longsight type is due rather to the influence of the intrusive sheets than of the main body of the Bushveld Plutonic Series (see below).

Compared with the writer's experiences of the metamorphic phenomena in Secoecoeniland, the total absence of staurolite in the present part of the Rustenburg District is remarkable, for in the altered shales of the eastern Transvaal this mineral is extraordinarily abundant. An explanation of the apparent anomaly is suggested below.

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* See A. L. Hall, *loc. cit.*, and "Report on Secoecoeniland" in this volume.

III. *The Malips River Type.*—To this class of metamorphic shales are referred all the varieties which combine holocrystalline structure with a habit more or less distinctly that of crystalline schists; that is, they represent a schistose Groothoek type. Arguments have been brought forward elsewhere* to show that the Malips River type is essentially a metamorphic rock, which, however, under the influence of great pressure has acquired specific structural features and a somewhat abnormal mineralogical composition, in which the Law of Volumes is expressed. In the Rustenburg District, altered rocks of this kind have so far not been met with, at least as far as the macroscopic habit is concerned, but the tendency to schistose structures is distinctly marked in some of the thin sections of the Groothoek type, especially in those taken from occurrences nearer the edge of the Bushveld margin. Here the clearly defined orientation of the biotite flakes is suggestive of pressure influences, while the increased abundance of muscovite points to the operation of the Law of Volumes. It is clear from arguments independent of petrographical characters, that the area has been subjected to pressure, but since this factor has been much less powerful than in the disturbed areas of the eastern Transvaal, the Malips River type is naturally more subordinate in the Rustenburg District.

(*e*) *Agents of Metamorphism.*

Enough has been said above to show, that the metamorphic rocks owe their alteration mainly to the influences of the body of the Bushveld Plutonic Series, and of the intrusive sheets within the upper half of the Pretoria Series. The influence of pressure is of secondary importance, and only affects a comparatively narrow horizon nearer the norite zone. It now remains to show how far it is possible to assign to each agent its own sphere of activity.

It is not difficult to fix the minimum distance to which the direct thermal influence of the main body of the Bushveld Plutonic Series was carried. In the first place, the number and thickness of the intrusive sheets along the Hex River section, as far down into the Pretoria Series as the south-western boundary of the farm Rooikloof (212), are not sufficient to account for the complete alteration of the far greater thickness of intervening shales. In the second place the rocks of the Groothoek type are always confined strictly to the upper horizons, and as soon as the zone of the less altered Longsight type is entered, the crystalline hornfels variety disappears. The latter is, moreover, remarkably uniform in character and indistinguishable from the altered shales lying *above* the Magaliesberg Quartzite, and in direct contact with the basic norite margin. For these reasons there can be little doubt, that the lower limit of the Groothoek type marks the minimum distance to which thermal effects of the Bushveld Plutonic were felt. Calculations based on this supposition give about 4,500 feet as the width of the contact aureole measured along the thickness. If this estimate is considered somewhat high, the enormous extent of the great Bushveld Plutonic Complex must be borne in mind. Compared with the width of the latter of over 100 miles, 4,500 feet does not seem an unreasonable value. Yet the presence of intrusive sheets within this contact belt has impressed results of its own on the altered shales which, as shown above, contain along the immediate contact with such intrusions, a purely local enrichment of ferro-magnesian constituents, which cannot be accounted for by the chemical composition of the original sedimentary rock, but represent a supply of basic material from the adjoining igneous rock; and such results are supported by strictly analogous observations in Secoecoeniland.

The agency of the intrusive sheets is seen in the Longsight type, and when the shales associated with any one intrusion are considered, it is frequently found that the degree of metamorphism varies with the distance from the line of contact. Hence it would seem that for this type of alteration, the influence of the main body of the Bushveld Plutonic Series has become subordinate. Also immediately below the Daspoort Quartzite occurs a horizon of altered sandy shales or greywackes, which are more strongly metamorphosed than the graphitic shales overlying the same quartzite. If therefore, the Longsight type also were due to the influence of the Bushveld Plutonic Series, the last-named horizon should on the contrary be more pronouncedly altered, as it lies nearer to the Bushveld. On the same supposition the thickness of the contact belt would rise to some 9,000 feet, which seems too high.

The pressure factor is not of great importance and is seen mainly in the orientation of the mica, observable in certain phases of the Groothoek type, and in the development of muscovite, for which the molecular volume is less than that of the sum of the constituent oxides. The general geological structure itself seems to show, that the pressure was less than in the Pretoria Series south of Haenertsburg. Staurolite has not so far been observed in the present portion of the Rustenburg District, yet it is extremely abundant in the metamorphic rocks of the eastern Transvaal. It is essentially a mineral characteristic of dynamic and not of contact metamorphism, also its actual molecular volume is less than that deduced from the constituent oxides. For

* Compare p. 53, and A. L. Hall, *loc. cit.*

these reasons it is not likely to be found, excepting where during metamorphism the sedimentary rocks were subjected to greater pressure; this view probably accounts for its prevalence in the folded Transvaal System of Secoecoeniland, where high pressures can be shown to have operated.

It follows from the above description that the metamorphism in the Rustenburg District is much more pronounced than along the same horizons further east near the Capital. A completely satisfactory explanation of this apparent anomaly is not easy to give, but the following considerations may help to remove some of the difficulties. In the first place the dip of the Pretoria Series near the Capital is considerably higher than further west, and in comparing the width of the contact belt due to the Bushveld Plutonic Series, due allowance must be made for this factor, when the width south of Rustenburg becomes appreciably reduced. Then again, in the neighbourhood of Pretoria, the strike of the Transvaal System is quite straight for a considerable distance, while west of Scheerpoort it begins to curve towards the north, and the evidence of pressure becomes increasingly stronger in the same direction. Such effects must tend to some extent towards lessening the cohesion of the sedimentary rocks, which therefore become more easily permeable to mineralising solutions. It is significant, too, that cordierite contact fels is first met with below the Magaliesberg Quartzite a little west of Scheerpoort, i.e. where the structural change begins. That pressure does tend to produce such results is conclusively shown in the presence of tourmaline in the Daspoort Quartzite of the Haenertsburg Gold-fields—that is in a rock usually possessing a high degree of cohesiveness.

When the metamorphism is reviewed from the point of view of the whole Bushveld Complex, the differences in the intensity of the alteration, which are so marked when definite and smaller areas only are considered, become more intelligible and are of an order, which could be accounted for by slight local variations either in the chemical composition of the shales or in the content of mineralising agents in the main body of the Plutonic Complex. The former point is indicated for instance by the marked preponderance of graphite in certain horizons above the Daspoort Quartzite near Steinbokfontein; even more so by the presence, in comparatively little altered chiastolite slate, of thin bands of thoroughly crystalline hornfels.* Such experiences tend to show the great variation which the shales exhibit in relative susceptibility to contact metamorphism. Apart from the metamorphism directly traceable to the main body of the Bushveld Plutonic Series, the variable degree in which the intrusive sheets are capable of inducing contact alteration may also be connected with their thickness, which we know becomes on the whole greater in a westerly direction. In comparing the thermal effects of such sheets attention must of course be confined to the Longsight type only, and then the difference between the Rustenburg and the Pretoria Districts are not so great as would at first sight appear, for already a little west of the Capital, near the Crocodile River, chiastolite slates have been met with.

5. Igneous Rocks.

The Igneous rocks within the Pretoria Series as developed in the present part of the Rustenburg District, fall into two groups of very unequal importance. The first of these comprises all those occurrences indicating true intrusive sheets, the second type representing an inter-bedded contemporaneous flow.

(*a*) *Intrusive Sheets.*

These invariably follow the strike of the enclosing sedimentary rocks and this fact, together with their metamorphic effect, both above and below, leaves no room for doubt as to their true relationship. Their mode of occurrence, behaviour in the field, topographical influences, and form of weathering agree with similar intrusions already described from the same horizons further east. In the upper portions of the series, the intrusions are much more numerous and also thicker than below the Daspoort Quartzite. Both above and below the Timeball Hill Series the shales are practically free from intrusions.

Petrographically the rocks belong to the gabbro, diabase, and diorite families. The first intrusion underlying the Magaliesberg Quartzite is well exposed on Magatos Nek, where it gives rise on the south side of the Zeerust main road to a prominent kopje. This type is made up essentially of large idiomorphic crystals of augite and plagioclase—approaching labradorite; somewhat abnormal is the presence of a little biotite. The structure is holocrystalline and provisionally the rock may be classed as a gabbro. Further west along the same section occurs another thick intrusion crossing the western half of Kraalhoek (283); this rock and another conspicuous sheet on Elandsdrift (717) show well marked ophitic structure with pyroxene and labradorite as the dominant minerals; they may therefore be classed as diabases. The next great intrusion crosses the Selons River at Moedwil and consists mainly of very pale greenish somewhat fibrous amphibole and plagioclase. It may be termed a diorite. Generally speaking, along the upper horizons the dominant ferro-magnesian constituent is pyroxene, while in the lower ones hornblende is more conspicuous. The felspar is fairly constant and is either labradorite or between that and bytownite. The colour throughout is pale bluish green.

* See p. 47.

(b) *Contemporaneous Rocks.*

A short distance below the Daspoort Quartzite occurs a thick mass of igneous rock, which behaves in the field like an intrusive sheet, but which probably represents an inter-bedded flow. The rock, wherever it has so far been found, is easily identified by the abundance of amygdaloidal quartz blebs, from which appearance it has sometimes been referred to as the "Vesicular Diabase." In the central Transvaal this sheet has now been followed for over 100 miles, always occupying the same relative position with regard to the overlying Daspoort Quartzite. In thickness it seems to increase considerably from east to west; where it crosses the Zeerust main road it has a thickness of about 1,500 feet, after making allowance for the low dip of the associated shales. Throughout the area, the rock shows very uniform characters, among which the numerous amygdales of white quartz are perhaps the most striking. It may be pointed out, that the same variety is also found in the Lydenburg District along the same horizon.*

The arguments in favour of a contemporaneous origin are derived both from the general field relationship as well as the petrographical habit of the rock. Regarding the former, it is not easy to realise how an intrusive sheet can maintain a strictly identical horizon over so wide an area, for one might reasonably expect to find it breaking through the strata sooner or later or sending off apophyses into the surrounding rock. Furthermore, the relationship to the shales both above and below is highly suggestive of a contemporaneous origin. These appearances can be best studied on the common boundary between Steinbokfontein (570) and Enkeldebosch (304), about nine miles N.N.W. of Koster Siding on the Krugersdorp-Zeerust Railway line, also on the farm Watervaal (66), a little east of the latter locality. Immediately underlying the Daspoort Quartzite is a true intrusive sheet, which metamorphoses the shales below into andalusite-chiastolite slates, but the intensity of this change becomes distinctly less as one approaches the underlying vesicular rock; hence the latter cannot have been the agent of metamorphism. From thin sections cut from samples taken right across this horizon into the upper portion of the vesicular mass, it seems likely that the latter rock also underwent some change, for granular devitrified portions are noticeable, which are not present in sections cut from the main body of this sheet. It is, therefore, highly probably that this rock was already present, when the intrusion of the upper sheet took place. If a comparatively thin sheet could induce the change of shales into andalusite slates, one would expect from a very much thicker igneous mass at least the same degree of metamorphism. Yet on Bankdrift (549), Doornpoort (550), and Vlakfontein (892) the contact of the vesicular rock with the underlying shales can be followed closely, and the latter are practically unaltered.

Sometimes the vesicular rock shows a true amygdaloidal structure, resembling that of undoubted lava flows, and here and there the vesicles seem to become more pronounced along the upper portion of the mass. Locally, e.g. south-west of Koster Siding, the quartz blebs become much larger and quite irregular in shape, giving rise, after prolonged weathering of the rock, to a kind of opaque dirty white gravel. Under the microscope, the groundmass is occasionally trachytic with minute felspar microlites, while there may also be a fair amount of isotropic matter in the groundmass; sometimes the fresh vesicles of quartz are surrounded by a conspicuous ring of glassy matter. The usual ferro-magnesian constituent is pale greenish acicular hornblende, while biotite sometimes occurs in subordinate amounts; the felspar is usually labradorite, though locally less basic varieties are found approaching andesite. Flow structure is not well shown. Slides cut from a number of different outcrops may show considerable variation in texture and habit of component minerals, so that it is not easy to give a single name to cover all characteristics. Provisionally the term vesicular hornblende-andesite may be used.

Taking all the above arguments together, the contemporaneous origin of this sheet seems fairly established. Moreover the occasional presence of a conglomerate immediately beneath it, e.g. on Dornkom (896), and especially along the same horizon in the Orighstad River Valley, combined with the presence of arenaceous deposits above its upper limit, would seem to indicate that it was poured out under shallow water conditions.†

* See A. L. Hall, "Note on Contemporaneous Igneous Rocks in the Pretoria Series of the Lydenburg and Rustenburg Districts." Trans. Geol. Soc. S.A., vol. xi, 1908.

† A. L. Hall, *loc. cit.*

V.

THE GEOLOGY OF THE GOLD-BEARING DISTRICT OF BLAAUWBANK,

WEST-NORTH-WEST OF KRUGERSDORP.

By A. L. HALL (*Geologist*).

CONTENTS.

1. Introduction.

2. Geological Features.

3. Nature and Distribution of the Auriferous Zones.

V.—THE GEOLOGY OF THE GOLD-BEARING DISTRICT OF BLAAUWBANK, WEST-NORTH-WEST OF KRUGERSDORP.

By A. L. Hall (*Geologist*).

1. Introduction.

In the present notes are described the various gold-bearing horizons lying to the west-north-west of Krugersdorp as far as the neighbourhood of Boons Siding on the Zeerust railway line, which have been worked with varying success since about the year 1890.

These occurrences lie along a rather narrow belt of country stretching from the farm Blaauwbank (104) through Cyferfontein, Vogelstruisfontein (317), Rietfontein, and Palmietkuil, for a distance of at least 16 miles towards the west, and occupy a fairly constant horizon in the general succession of the shales and quartzites of the Pretoria Series with which they are associated.

2. Geological Features.

The beds, in which the gold-bearing formations are found, belong to the lower portion of the Pretoria Series overlying the quartzites of the Timeball Hill horizon, and consist entirely of shales and thin quartzites, with which are associated intrusive igneous rocks, either in the form of sheets of diabase and allied types, striking in conformity with the general distribution of the sedimentary rocks, or as dykes of elaeolite-syenite.

Throughout this area the beds show a fairly uniform dip in a general northerly direction, usually not exceeding 10 degrees, but locally they are thrown into minor folds, which may develope a high dip for a short distance, but which are never sufficiently pronounced to complicate the general structure. Faults are very few, the most important being the great dislocation passing through Oliphants Nek in an east-south-easterly direction,* owing to which the beds are broken and displaced, as shown for instance in the outcrop of the main quartzite of the Timeball Hill Series on Hartebeestfontein (702) (see Map, Plate IX).

The lowermost formation in the country rock is that of the quartzites of the Timeball Hill Series, which also form a very useful geological landmark, since they are nearly always slightly magnetic along certain horizons, while their colour is redder than that of the next higher or Daspoort Quartzite, constituting the elevated tract of ground known as the Witwatersberg, north of Boons Siding. The southern face of the deep valley of the Blaauwbank River is made up of this quartzite, and from here it can be traced towards the west as far as the fault alluded to. Here it undergoes a slight displacement towards the north, but can be easily picked up again close to the Jameson Road, whence it continues unbroken to Tafel Kop, giving rise to a gentle feature, locally emphasised by the occurrence of pointed kopjes such as Coetze Kop, some miles south of Boons Siding.

Overlying these quartzites comes a considerable thickness of thinly bedded soft shales, varying in colour, but often greyish brown or dirty bluish grey and in some places, e.g. on Blaauwbank and Kosterfontein, folded and puckered on a small scale, a result probably due to the system of movements which have affected the Transvaal System south-east of Rustenburg. The slates are occasionally spotted owing to metamorphism by the igneous rocks.

When the latter are present in the form of intrusive sheets, they run out at the surface parallel to the strike of the associated sedimentary rocks, e.g. on the northern portion of Rietfontein (652). Such rocks are medium to fine-grained crystalline dark greenish varieties belonging to the diabase, diorite, or gabbro families, closely resembling similar intrusions always found in the Pretoria Series elsewhere. Structurally, they behave like a sedimentary bed in following the general dip and strike, while their thickness is never very great.

* See Sheet No. 4, Rustenburg (Geological Survey Map).

The dyke rocks show a very characteristic appearance, and are readily distinguishable from the above sheets. They were only met with—within this area—on the extreme western portion of Blaauwbank (104), on Kosterfontein (108), and on the southern portion of Vlakfontein (663). They clearly belong to the same intrusions which have been followed from the norite zone of the Bushveld Plutonic Series on the north into the Magaliesberg, which they cross near Breedts Nek, whence they are traceable into the neighbourhood of Blaauwbank, sometimes making a low wall-like outcrop. Their thickness probably does not exceed 40 or 50 feet. The rocks belong to the syenite family; some are true elaeolite-syenites, and much more coarsely crystalline than those forming the intrusive sheets. A common feature is the presence of large bluish-white tabular orthoclase or anorthoclase crystals. The rocks are on the whole much lighter in colour, but one dyke crossing the main road a short distance south of the Zeerust Railway, near the western end of the "Golden Kopje" on Blaauwbank is uniformly deep red owing to the prolonged influence of weathering.

Overlying this great body of shales with their intrusive sheets comes another mass of igneous rock of considerable thickness, possessing characteristics of its own, which enable it to be readily distinguished from both the dykes and the true intrusive sheets. This mass extends roughly along the right side of the Zeerust Railway, which crosses it obliquely to the strike near Boons Siding. On the whole it is poor in outcrops, but one frequently finds very good though small and patchy exposures, almost invariably showing a greenish crystalline rock, characterised by numerous irregular blebs of quartz, causing a kind of amygdaloidal appearance, well seen on the weathered surface. The blebs are usually about the size of a bean, but vary much in dimensions, and may locally become considerably larger. The upper and lower boundaries of this "Vesicular Diabase" are difficult to define, and a rapid change in the colour of the soil from greyish to bright red frequently forms the only indication of the transition from the sedimentary to the igneous type. Evidence has recently been collected, which shows, that this amygdaloidal rock represents a contemporaneous flow.*

The occurrence and recognition of this rock is of importance in limiting the distribution of the gold-bearing horizons towards the north.

3. Nature and Distribution of the Gold-Bearing Zones.

At the time of the writer's visit,† mining operations were practically confined to the two farms Vogelstruisfontein and Rietfontein (652), some 6 miles south-east of Boons Siding, though there are indications that much of the surrounding area on the west and towards Blaauwbank on the east has been to some extent prospected. On the latter farm, the little hill known as the "Golden Kopje" shows signs of much activity in the past and, although situated about 11 miles east of Vogelstruisfontein, it presents features much like those met with on the latter farm where work is still in progress, so that these occurrences may be conveniently described together.

The gold is found both as alluvial as well as in inter-bedded reefs, and appears to follow a mineralised belt bounded on the south by the Timeball Hill Quartzite described above. Its northern edge may be taken along the base of the amygdaloidal lava-flow, recognisable, as already pointed out, by the occurrence of irregular quartz blebs. While at present the workings are situated within this belt and the mineralisation is apparently confined to the limits above given, there is no evidence to show that the gold occurrences must necessarily be confined to this horizon.

The alluvial gold occurs in so-called "paddocks," i.e. irregular patches composed of dark greyish brown soil up to 2 feet in depth, sometimes lying directly at the surface, sometimes covered by several feet of barren over-burden. In such auriferous soil is also sometimes found a kind of gravelly dirt composed of quartzose fragments, one or two inches across and resembling disintegrated reef matter. Immediately underlying these "paddocks" are thinly-bedded shales. The ground in some workings is ploughed previous to being treated by running water; the precious metal is then isolated by mechanical means. The gold is obtained in the form of small, coarse irregular nuggets of dull metal, apparently not much worn and often incrusted with a material resembling opaline quartz. One nugget weighing 9 ozs. has been found at one locality, but from 2 to 3 dwts. per load would probably be a good average yield of a typical alluvial "paddock."

The view that the precious metal is derived by disintegration of the gold-bearing quartz reefs occurring *in situ* in close proximity is the simplest explanation of its source, and seems also indicated by the occurrence of quartz fragments in the metalliferous soil. There is, moreover, no good evidence to be obtained from the

* A. L. Hall, "Notes on Contemporaneous Igneous Rocks in the Pretoria Series," Trans. Geol. Soc., S.A., vol. xi.
† November, 1907.

present topography of this district to support the theory of the gold having come from some distance, and having no genetic connection with the quartz reefs.

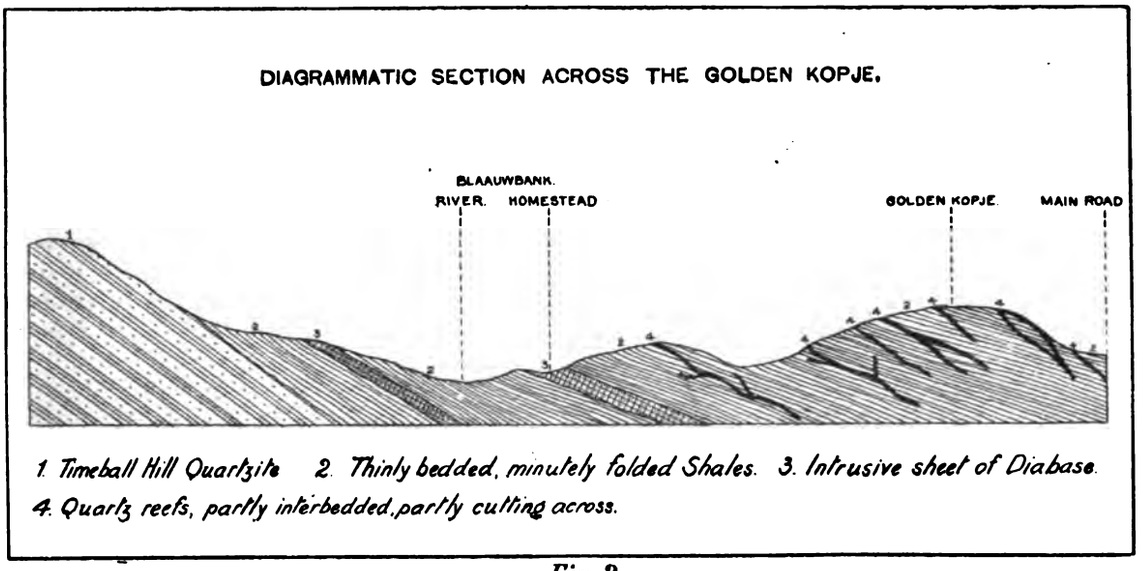
DIAGRAMMATIC SECTION ACROSS THE GOLDEN KOPJE.
BLAAUWBANK.
RIVER.
HOMESTEAD
GOLDEN KOPJE.
MAIN ROAD
1. Timeball Hill Quartzite 2. Thinly bedded, minutely folded Shales. 3. Intrusive sheet of Diabase.
4. Quartz reefs, partly interbedded, partly cutting across.

Fig. 2

The same thick succession of shales, with which these "paddocks" of alluvial gold are associated, also contains numerous so-called quartz-leaders, the relationships of which to the country rock are well exposed on Vogelstruisfontein, Rietfontein, and at the "Golden Kopje" on Blaauwbank. While these reefs may locally outcrop with a strike parallel to that of the associated shales, they are frequently seen to cut across the bedding-planes of the latter (see Fig. 3), and the same vein can sometimes be traced continuously from a true inter-bedded reef into one cutting across the planes of stratification of the shales. On the "Golden Kopje" a type of reef occurs in many respects resembling that on Vogelstruisfontein, but the shales have a much higher average dip—about 20 degrees—and there is no doubt that the beds have been much disturbed on a small scale, since locally the dip may rapidly rise to 40 degrees. On the whole, the reefs are more truly interbedded than in the workings further west, but on the summit of the kopje leaders occur inclined at high angles and cutting across the strata (see Fig. 2).

The hanging and footwalls are usually well defined against the shales of the country rock, which may be puckered and minutely folded; as far as one can judge between localities so far apart, the horizon of the reefs on the "Golden Kopje" roughly corresponds to that of the highest point on the Vogelstruisfontein mynpacht, a correlation supported by the position of the underlying intrusive sheets with reference to the Timeball Hill Quartzites.

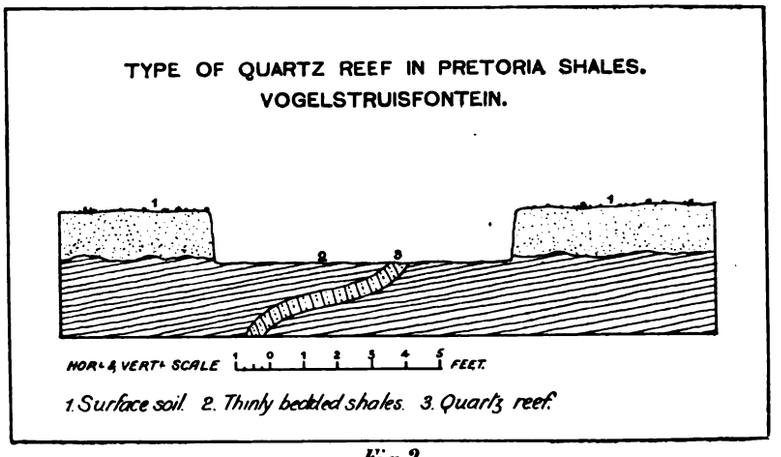
TYPE OF QUARTZ REEF IN PRETORIA SHALES.
VOGELSTRUISFONTEIN.
HOR.& VERT. SCALE 1 0 1 2 3 4 5 FEET.
1. Surface soil. 2. Thinly bedded shales. 3. Quartz reef.

Fig. 3

The reefs vary in thickness from about 2 feet down to mere stringers, while at one point on the "Golden Kopje" where the old stopes are seen, pillars of reef 2½ feet thick are found. Any one reef does not maintain much continuity for any distance; thus a reef 12 inches thick may die down to 1 inch in about 3 yards; in other cases a reef of medium thickness may rapidly expand into "pockets" 8 feet across. The gentle folding of the associated sedimentary strata is well shown at the Vogelstruisfontein mynpacht, and where the beds assume the form of a low saddle the richer parts of the reef may lie at the crest.

The deposits are typical quartz reefs consisting mainly of rather hungry looking quartz, which varies much in richness. While one occurrence yielded 2¾ ozs. per ton, others were barren: about 8 dwts. per ton represents a fair average. Where the material of the reef is much broken and jointed, one finds reddish earthy and clayey matter. Iron pyrites does not usually occur, but the quartz may be full of irregular cavities lined with hydrated iron ore and limonite, which may be regarded as due to the oxidation of original sulphides of iron. Nowhere have the workings gone far enough to enter the unoxidised zone. Frequently the reef is richer in gold as it becomes less quartzose and more earthy. In the "Golden Kopje" a little peacock ore occurs with the quartz. Visible gold seems very rare in the reefs, which may sometimes be underlain by very soft, highly micaceous earthy and shaly bands, the so-called "clay leaders"; these are likewise auriferous.

The general appearance of these reefs, their occasional rusty-brown and earthy character, as well as their cellular and honeycomb structures, indicating the oxidation of sulphide of iron, recall the nature of the inter-bedded quartz reefs associated with the base of the Pretoria Series and the Dolomite in the Pilgrims Rest District. In the latter area, however, the reefs are always true interbedded deposits, not cutting across the bedding planes of the country rock; hence the occurrences in the Blaauwbank and Vogelstruisfontein area occupy a position intermediate between the true inter-bedded reefs of the Lydenburg District and those of the Pretoria Series at Scheerpoort, west of Pretoria, where the reefs are invariably present as "leaders," always cutting across the bedding planes.

While, therefore, the gold-bearing deposits of this district cannot be said to be of first-class importance, they seem to hold out a good prospect of success for private enterprise on a modest scale, especially if a more reliable water-supply could be obtained.

VI.

THE GEOLOGY OF THE NEIGHBOURHOOD OF RUSTENBURG.

By W. A. HUMPHREY (*Geologist*).

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4. The Transvaal System.

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VI.—THE GEOLOGY OF THE NEIGHBOURHOOD OF RUSTENBURG.

By W. A Humphrey (*Geologist*).

1. Area.

The country described in the following report comprises an area of some 1,330 square miles. It lies in the Rustenburg District and is bounded on the north and west by the Elands River. The eastern boundary is formed by a line coinciding roughly with the course of the Sterkstroom from Breedt's Nek in the Magaliesberg to its junction with the Crocodile, whose course it then follows as far as its junction with the Elands River. The escarpment of the Magaliesberg from Breedt's Nek forms the southern boundary as far as Magato's Nek, from which point the line runs some miles south of the main Rustenburg–Zeerust coach road, cutting the Elands River on the farm Doornkom (896).

2. Physical Features.

(*a*) *Surface Relief.*

Topographically the area to be described may be divided into two parts, depending for their main characteristics upon their relative position with regard to the Magaliesberg. This range extends in a wide arc from the south-eastern corner of the terrain, striking thence roughly in a westerly direction as far as Oliphants Nek, at which point it turns north-west and continues in this direction until it crosses the Elands River at Onderstepoort.

The difference between the topography in the two areas lying on either side of the Magaliesberg is well marked, and is to be explained principally upon geological lines.

Lying within the arc formed by the Magaliesberg are wide and continuous zones, whose physical characteristics depend upon the fact that all the rocks composing them are of igneous origin, and this lends a distinctive character to the landscape.

Immediately to the north and east of the Magaliesberg is a broad monotonous band of black "turf" soil, which forms a wide and shallow depression. This depression is flanked to the north by a conspicuous line of black and sombre bush-covered kopjes, which, together with the black turf depression, forms the zone of the norite, varying in width from eleven to nineteen miles. The roads here are hard and good in winter; after rain, however, they are almost impassable for heavy transport, except alongside the rivers, where a red alluvial drift often covers the norite. Hardened roads are in course of construction, linking up the surrounding country with the railway, which has been constructed in this part of the country entirely along the norite zone. Bush is only found on the kopjes over this belt, the low-lying turf soil being covered with rather scanty grass.

Proceeding north across this zone, the soil becomes sandy as one leaves the norite, and reaches the granite area. Here the scenery is typical of the Bushveld, long rolling bults succeeding valleys of varying shallowness.

In contrast to this type of scenery, the country lying to the south and west of the Magaliesberg consists geologically of alternations of sedimentary rocks belonging to the Pretoria Series, whose dip-slopes and escarpments take the place of the rounded hummocky outlines of the igneous masses. The typical "banken" scenery usually displayed by the Pretoria Series is, however, somewhat obscured here owing to the bend of the series to the north-west and to the diminution in the angle of the dip. The escarpment of the Magaliesberg becomes less conspicuous as it is followed northwards from Magata's Nek. It overlooks the wide and low-lying valley of the lower Selons River, whose western slopes gradually ascend towards the dip-slope of the Daspoort Quartzite. This gentle incline forms an elevated plateau, and is cut across by several streams whose courses lie in narrow but fertile valleys, enclosed by well-defined kranzes. This part of the country thus furnishes broken and picturesque scenery. A double escarpment forms the limit of this elevated dip-slope on the west, running through the farm Ebenezer (274) and trending northwards. It bends round to the west on the western boundary of the farm Lemoenfontein (357), and crosses the Elands River at Lindley's Poort.

The country lying to the west and south of this escarpment is rough and broken, on a small scale, but furnishes no topographical features worthy of special note.

(*b*) *Drainage.*

The general slope of the country is to the north, and, with the exception of a narrow band of country draining into the Sterkstroom and Crocodile Rivers, the whole of the area belongs to the subsidiary drainage basin of the Elands River, which bounds the area on its western and northern sides. The most important of its tributaries are the Hex River and the Selons River. The north-western extension of the Magaliesberg divides the Selons River basin from the various spruits which flow into the Elands River east of Onderstepoort, and from the streams tributary to the Hex River, which rise along its dip-slope. The Magaliesberg carries a large supply of water, and fine springs feed perennial streams along the whole of its northern slopes. These springs are of such volume that it is exceedingly doubtful that their sources can be local. Situated towards the summit of the Magaliesberg dip-slope, they supply the head-waters of the Sterkstroom and the spruits rising to the west of Breedt's Nek, as far as Magata's Nek. The question of the origin of this water is discussed under the heading of water-supply.

Soon after entering the granite area both the Hex River and the Sterkstroom are reduced to a series of pools in the dry season, and the same may be said of the Elands River itself, which has a perennial surface flow until a few miles below Lindley's Poort, after which, in a dry season, it consists of pools of diminishing frequency. These pools, however, remain fresh, and are connected by an underground flow through the sand and beneath the accumulated boulders which often cover the bed of the river.

The Selons River carries no permanent surface flow in the dry season, although its tributaries, the Koster River and the spruit which joins it on Stromrivier (265), are perennial streams whose water is extensively used to cultivate winter crops.

3. Principal Geological Formations.

The sedimentary formations occupying the area (see Sheet 4, Rustenburg) belong exclusively to the Transvaal System, of which only the upper portion, consisting of the Pretoria Series, is here seen. In these beds are found the usual diabasic intrusions.

In addition to the Pretoria Series, rocks belonging to the Bushveld Igneous Complex cover the greater portion of the area. Of these the norite and associated basic rocks have the most extensive distribution, while the syenites are represented by a series of dykes cutting through both norite and red granite.

The rocks of the area may be classified as follows :—

Sedimentary.

Transvaal System.—(*a*) Pretoria Series.
- Daspoort Beds.
- Magaliesberg Beds.

(*b*) Isolated patches surrounded by the Bushveld Plutonic Series.

Igneous.

Intrusive.—Bushveld Igneous Complex.
- Norite and Basic Rocks.
- Red Granite.
- Syenite.

Diabasic Intrusions in the Pretoria Series.

Contemporaneous.—Amygdaloidal Lavas.

4. The Transvaal System.

Only the uppermost portion of this system is here represented at the surface, the sedimentary rocks being confined to the higher members of the Pretoria Series. These rocks are found in the north-western portion of the area, and include beds from the Daspoort horizon upwards.

The Pretoria Series in this area undergoes an abrupt change of strike, the direction changing from north and south to almost due east and west. The dip of the series is low, rarely exceeding 5 degrees, which, together with an increasing thickness westwards, gives the series its great surface development in this locality.

(*a*) *The Pretoria Series.*

Daspoort Beds.—The lowermost member of this horizon is a thick band of well-bedded shales of a normal type. These contain several thin intrusions of diabase which are somewhat irregular in their behaviour, and apparently die out on the western bank of the Elands River. This horizon is overlain by a thin bed of quartz conglomerate, which separates it from the overlying "vesicular diabase." This conglomerate has a

siliceous cherty matrix, and the enclosed pebbles are usually rounded and water-worn, and consist of fine white and grey quartzite. The bed is only a few feet in thickness, but forms a persistent feature over the small portion of the area where it occurs.

Above this conglomerate is a great thickness of vesicular diabase, which is overlain by a bed of very much altered black shale. The fact that the metamorphism is more intense towards the upper portion of the shale shows that it is probably due to the comparatively thin overlying diabase, and not to the vesicular rock which underlies it. It is in parts very ferruginous, containing much magnetite. Near the contact with the overlying intrusion a hand specimen of this rock shows a granular structure and a greenish grey colour, with mica as the only distinguishable macroscopic constituent. Under the microscope the rock is seen to consist principally of andalusite, with large flakes of very pleochroic biotite distributed evenly throughout. Occasionally the andalusite shows faint remnants of the graphitic inclusions which are characteristic of chiastolite. With the biotite are occasional intergrowths of muscovite. Another type shows biotite as groundmass in undulating bands and aggregates, in which large andalusite crystals occur often with a margin of chiastolite. This shale in its less altered condition is siliceous, and would be better described as a shaly sandstone. It forms an escarpment weathering to a yellowish colour at the surface, and simulates the quartzite escarpments which occur higher up in the series. This can be well seen along the Elands River on the farm Rustvoorby (895).

These rocks are very similar in character to those found by Mr. A. L. Hall in the Lydenburg District in the same horizon of the Pretoria Series.* Their metamorphism is due primarily to the local influence of the intrusive sheets, and decreases in intensity and character with increasing distance from the intrusions. This type of metamorphism Mr. Hall has called the Longsight type (from the Lydenburg District). It is characterised by the presence of biotite, andalusite, chiastolite, and staurolite, with occasional cordierite, in contrast to the Groothoek type due to the wide reaching influence of the main Bushveld Igneous Complex, which gives rise to characteristic cordierite-hornfels showing no trace of the original shale.

The Daspoort Quartzites, owing to their low dip, which varies from 4 to 6 degrees, form an extensive dip-slope of plateau-like character, in which deep valleys, exposing the underlying diabase and shale, have been excavated by the streams. The quartzites consist of two hard beds, divided by a thinner band of sandstone, which weathers more rapidly than the quartzite, to which it gives the character of a double escarpment. On the farm Dwarspruit (598) occurs a large outlier of Daspoort Quartzite, which is separated from the main outcrop by the underlying shale and diabase, exposed in the valley of the spruit flowing through the farm. The beds must here have experienced a slight dip-fold, as a continuance of the dip of 5 degrees from the outlier would bring the main quartzite horizon many feet below its actual position. The same phenomenon occurs on the farm Waterval (596), where an inlier of diabase and shale occurs in the valley between two exposures of quartzite. This explanation is not quite satisfactory, however, in this case, as the overlying quartzite to the north-east is quite thin and cannot represent the whole horizon. It is possible that locally minor faulting may have taken place here in connection with the bending of the series, the axis of the fold passing through this farm.

The Magaliesberg Beds.—This horizon consists of shale beds separated by intrusive diabases, and overlain by the thick quartzites of the Magaliesberg.

The shales in this locality are all more or less altered. Two rather thin beds are separated from the Daspoort Quartzites, and from each other, by intrusions of diabase. The lower of these shows signs of considerable metamorphism. Large needles of chiastolite are scattered throughout the rock, which, however, never loses its shaly character. Both of these beds are exceedingly graphitic in parts, the upper one especially, throughout the whole of its outcrop in the district. Under the microscope it shows little else than graphite, with an occasional flake of muscovite. The lower bed consists of a rock in which the shaly character still persists, and under the microscope is seen to consist to a large extent of biotite in fine sinuous bands and oblong crystals. Large crystals of chiastolite, showing the typical arrangement of the inclusions, are common on the farm Rietfontein (299). This band becomes graphitic when followed to the north and loses its other characteristics.

The higher shale beds of this horizon show the Groothoek type of alteration. They entirely lose their shaly appearance, become crystalline and lustrous in the hand specimen, and show no mineral macroscopically determinable other than mica. Under the microscope they show plentiful metamorphic biotite and cordierite, with occasional andalusite crystals. Sometimes the rock consists almost entirely of cordierite and its inclusions. The shales immediately underlying the Magaliesberg Quartzites furnish practically no outcrops, occasional highly weathered and disintegrated exposures being seen over a few square yards.

* A. L. Hall, "On Contact Metamorphism in the Pretoria Series of the Lydenburg and Zoutpansberg Districts," Trans. Geol. Soc., S.A., Jan., 1908, vol. xi; and "The Geology of the Haenertsburg Gold-fields," p. 45 of this Report.

The Magaliesberg Quartzites, owing to their resistant character, constitute the dominant physical feature of the district. Traced from Breedt's Nek, where they are from 400 to 500 feet in thickness, to the west, they become thinner and continue to diminish in thickness until at Onderstepoort they do not exceed 150 feet.

In spite of this diminution, their breadth of outcrop does not suffer in proportion, owing to the fact that they have been subjected to pressure, exerted at right angles to their strike, and this has resulted in the production of a double fold, consisting of a syncline followed by an anticline, which persists almost up to the Elands River.

At Breedt's Nek the outcrop consists of a broad dip-slope of from 5 to 8 degrees inclination to the north, while on the farm Rietfontein (431) the dip undergoes a gradual change, until in the bed of the spruit which drains the farm, dips of 8 degrees to the S.S.W. were registered, increasing to 25 degrees on the northern slopes of the valley. On the farm Rhenosterfontein (346) the dip is again to the north.

By following the range further to the west constant and numerous sections can be found illustrating this double fold, one of the best being described in a previous Report,* where the crest of the anticline has been weathered down, exposing a valley shut in by quartzite escarpments, dipping to the north and south respectively.

Perhaps the best and most typical section is that to be found to the south-west of the town of Rustenburg. The farm Rietvlei (824) consists almost entirely of high ground forming the crest of the Magaliesberg, whose powerful escarpment faces and overlooks the low-lying ground to the south-west. For about two miles north-east of the main escarpment the farm consists of a broad shallow valley, formed of a syncline of quartzite beds, being bounded to the north-east by another escarpment facing towards Rustenburg, with a dip to the south-west. On this side the dip is considerably higher than on the south-west, and amounts to 65–70 degrees to the north-east along the north-eastern limb of the anticline, which is a much sharper fold than the syncline. Further north-west, Magatos Kop forms an interesting feature. It consists of quartzite whose outcrop forms a smooth hemispheroid. The north-eastern and south-western sides of this kopje consist of dip slopes of quartzite, showing in this case the unbroken anticline. Here and there along the chain of the Magaliesberg the syncline of quartzite is still covered by thin overlying diabase, notably on the southern portion of the farms Boekenhoutfontein (336), Goedgedacht (200), and Rietvlei (350).

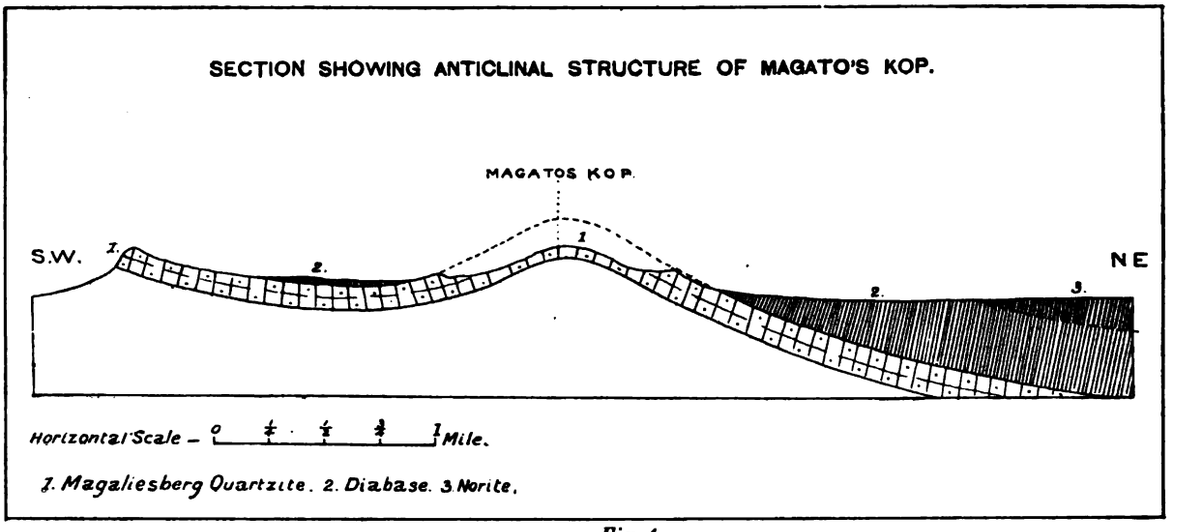

Fig. 4

On the latter farm the diabase spreads out and covers the syncline, leaving only a portion of the easterly arm of the quartzite anticline visible. In these quartzites immediately south-east of Magatastad, the structure has been disturbed, probably by local minor breaks involving the anticlinal portion of the fold, which renders the true relation of some of the beds difficult of determination.

Immediately to the south of Rustenburg, the structure is complicated by faulting. The quartzites lying immediately to the west of the main road from Oliphants Nek to Rustenburg do not belong to the main

* Annual Report of the Geol. Survey for 1906, p. 121.

Plate VII.

Fig. 1.—**The Kloof, Rustenburg,** showing north-eastern arm of Quartzite Anticline cut through by the Dorp Spruit. (The beds dip towards the observer.)

Fig. 2.—**Bands of Chromite, alternating with Hypersthene Rock, Kroonendal, near Rustenburg.**
(The two hammers rest upon Chromite.)

SUMMERHILL SCHOOL

Magaliesberg horizon, but are disconnected from the main mass of the Pretoria Series. They represent portions of the series which were detached and broken off when the igneous rocks of the Bushveld Plutonic Series were intruded.

(*b*) *Isolated Patches Enclosed by the Bushveld Plutonic Series.*

Fragments of the Transvaal System are found in several places surrounded by outcrops of igneous rocks belonging to the Bushveld Complex. West of Beestekraal (296), on the Crocodile River, is a series of quartzite ridges and kopjes which extend on to Welgevonden (351), overlooking the Hex River. These are disconnected and separated from each other by granite, although they all have the same general strike and dip S.S.E.

On Sandfontein (589) is a small ridge of quartzite, while on the left bank of the Hex River towards its confluence with the Elands River occur several quartzite kopjes. All these occurrences show the normal white or grey quartzite of the Pretoria Series type. On the Elands River, on the farm Klipplat (353), quartzite occurs on both banks of the river, while on Tweerivier (823) is a fairly extensive outcrop of dolomite, with occasional small ridges of banded ferruginous quartzites. This is described in connection with the more extensive development of rocks of the Transvaal System which are met with further north.

Along the boundary between the Granite and the Norite is a series of quartzite ridges fairly continuous from the Sterkstroom, north of Berseba mission station, to Bierkraal, some miles west of the Hex River. These quartzites always appear along the line of junction between the two igneous rocks, and occasionally form hills of considerable height.

North of Breedt's Nek, and at intervals a short distance north of the Magaliesberg, are found further outcrops of this series of quartzites, separated from the main Magaliesberg Quartzites by a considerable thickness of diabase. Thus on the farm Buffelspoort (668) these rocks are of considerable thickness, and consist of two well-marked hard and resistant zones, separated from each other by a softer zone of black banded metamorphosed rock, which weathers more easily and forms comparatively lower ground between the two ridges. This rock is black and glistening in the hand specimen, evenly banded, and probably represents an altered shale. On the east these rocks are separated from the main mass of Magaliesberg Quartzite by diabasic intrusions; on the west, however, they diminish in thickness and, by means of two comparatively narrow quartzite ridges, apparently join up with the Magaliesberg Quartzites.

Similar quartz ridges are found at various points along the chain, those lying to the south of Rustenburg forming considerable hills. They extend from immediately south of Rustenburg to within a mile of Oliphants Nek, and consist of one main quartzite horizon of no great thickness, having diabase both above and below it. To the north of Rustenburg this horizon is represented by a few isolated kopjes.

On the whole these quartzites resemble those of the main Magaliesberg range very closely, although occasionally they are coarser in texture. This is probably due to recrystallisation caused by the intrusion of the Bushveld Plutonic Series.

The presence of these isolated patches of the Transvaal System scattered through the Red Granite area, and along its junction with the norite, is exceedingly interesting, and the fact that the lower beds of the system are also included is important.

There can be no doubt that these scattered fragments of the Transvaal System owe their position within the limits of the Bushveld Plutonic Series to the mode of intrusion of the latter. During the invasion by the igneous magma, fracturing and folding on a large scale must have taken place, and it is conceivable that large and small portions of the sedimentary rocks may have been broken off and left surrounded by the intrusive masses.

5. Igneous Rocks associated with the Transvaal System.

(*a*) *Intrusive.*

The igneous intrusions which are so characteristic of the Pretoria Series occur in this area without any sensible variation from the types found further east and described in previous reports.

A noticeable feature is the great amount of contact metamorphism exercised by the intrusion lying immediately below the Daspoort Quartzites, the underlying shales being intensely altered along the contact, and the rock almost entirely recrystallised.

(*b*) *Contemporaneous.*

The horizon in the Daspoort shales known as the "vesicular diabase" attains a great and increasing surface development as the series is followed westward. This rock presents considerable differences from

the diabasic intrusions with which it has usually been classed. Mr. G. G. Holmes* in a paper read before the Geological Society of South Africa considers that the Zeerust District affords good evidence that we have to deal here with a true flow. In the area described in this report, the evidence in favour of regarding this rock as representing a flow, contemporaneous with the deposition of the beds of the Daspoort horizon, is not nearly so strong and convincing as that brought forward by Mr. Holmes. Nevertheless, what evidence is available, namely, the amygdaloidal character of the rock, the presence of glass surrounding the amygdales, and the absence of any contact metamorphism in the overlying shales near the contact, tends to support this view. This rock, as suggested by Mr. A. L. Hall,† is probably a basic lava of andesitic type.

6. The Bushveld Igneous Complex.

(a) Norite and other Basic Rocks.

The area over which these rocks occur constitutes a broad belt striking roughly north-west to south-east. Along the course of the Hex River it attains its greatest breadth, the distance from Waterkloof (4) to Kaffirkraal (352) being nearly 19 miles. The width of outcrop decreases to the north-west, measuring barely 11 miles along the Elands River.

This zone is divided into two well marked horizons. The lower furnishes very few outcrops except along the rivers, and forms topographically a broad depression covered with black turf soil. In contrast to this, the upper horizon is characterised by a series of dark and rugged kopjes. The soil here is the same as that of the lower horizon and the whole zone is almost impassable for heavy transport in wet weather, except along hardened roads or along the river banks where alluvial drift forms a covering to the norite soil. Occasionally, over considerable areas, a fine and more compact reddish soil is found, the distribution of which depends apparently upon the composition of the underlying rock, as well as upon the relative distribution of hill and valley. In areas occupied by this soil the underlying rock often appears to be less felspathic and to contain more ferro-magnesian constituents. In places where the norite carries iron ores red soil is almost invariably present.

The principal areas where the prevailing black turf soil gives place to this red soil are as follows :—In the neighbourhood of Stuurman's Kraal, north of Magatastad ; parts of the farms Boschkopje (685) and Styldrift (583), west of the Boschhoek Spruit, south-west of Kana Mission Station along the main road ; portions of the farms Oorzaak (568), Rietfontein (290), and Boschkopje (685), and at intervals on the banks of the Sterkstroom.

An examination of these areas reveals the fact that in some cases the change in the character of the soil is partially due to the action of sluits in bringing down sandy material from the Magaliesberg, which modifies the prevailing black turf soil, and makes it more easily drained. The first two mentioned farms illustrate this, also the various expanses of red soil along the Sterkstroom. On the other hand, the red soil area of Boschkopje (685) is undoubtedly due to the character of the underlying rock which is highly ferruginous, while at Oorzaak the norite is poor in felspar and rich in ferro-magnesian minerals.

On the farm Arnoldstad, south-east of Rustenburg, occurs an outcrop of rock in which practically the only mineral is hypersthene, in rounded crystals and grains. The hand specimen is a darkish olive-green rock of granular texture, and must be classed as a hypersthene-pyroxenite. This rock immediately underlies the chromite, to be presently described.

Chromite has been found at several places in this district associated with the norite. It usually occurs in the lower portion of the horizon, and is described in the section dealing with the economic geology of the district.

In the upper portion of the norite, magnetite forms a continuous band, extending roughly parallel to the general strike of the norite, and quite close to its upper margin. Occasionally more than one band of magnetite was seen, but outcrops are not numerous except in certain localities. The apparent thickness of the bands is considerably greater than it is in reality, owing to the magnetite having given a distinct character to the soil for a considerable distance from its actual occurrence. This horizon has been fully described in previous reports.‡

The actual boundary between the Norite and the Red Granite is nowhere well marked, and no contacts or intermediate zones were seen in the present area. The junction between these two rocks is, however, often marked by quartzites, which form prominent kopjes and short ranges. These have already been referred to

* Holmes, Trans. Geol. Soc., S.A., vol. viii, p. 168.

† A. L. Hall, "Note on the Contemporaneous Rocks in the Pretoria Series of the Lydenburg and Rustenburg Districts," Trans. Geol. Soc., S.A., vol. xi.

‡ Annual Report of Geol. Survey for 1904, p. 73. Annual Report of Geol. Survey for 1905, p. 73.

in the description of the Transvaal System. Where there is no quartzite the contact between the Norite and Granite is usually veiled by surface sand. The contact is usually along a depression with granite on the higher side, or towards the foot of a granite bult.

(*b*) *The Red Granite.*

This rock occupies the north-eastern portion of the area, and gives rise to the typical swelling bults and rounded outlines which so often characterise granite areas. The outcrops usually take the form of large gently rounded masses of evenly weathered rock, while the typical granite kopje of piled up boulders is less frequently to be seen.

The character of the granite varies somewhat, a red felspathic type being developed over limited areas. In parts it is ferruginous, as on Welgevonden (351), where prominent kopjes occur with a roughly bedded structure. Over the greater portion of the area, however, a normal coarse-grained biotite-granite is developed. Dykes of syenite cut through its north-western portion, and these strike generally in the direction of the Pilandsberg. At different points along the margin of the granite abutting upon the norite, exposures of graphic granite occur showing beautiful granophyric structure. Occasionally they consist entirely of graphically inter-grown quartz and felspar, and these types graduate into others with considerable ferro-magnesian content.

(*c*) *Syenite.*

This rock occurs exclusively as dykes, which are probably all connected with the extensive masses of syenite exposed in the Pilandsberg towards which, without exception, all their outcrops are directed.

Traced from the Pilandsberg six separate dykes are found along the Elands River, some of which die out after showing a distinct outcrop for some five or six miles, two only being practically continuous over the whole area. These two are the same as those previously described as occurring south of Breedt's Nek.* Both are elaeolite-syenites, one having a prevailing pink colour (No. 1), while the other is grey (No. 2). No. 1 crosses the Elands River on the farm Rhenosterfontein (887), where norite is the country rock. It cuts the magnetite bands and passes over into the granite showing always a ridge-like outcrop. Its strike runs parallel to the line of junction between the Norite and Granite for some 12 miles, keeping about two miles to the north-east, then returns to the norite on Kafferskraal (352), where it cuts through the quartzites which here separate the igneous rocks. From this point, where it crosses the Hex River, it extends to Beestkraal (286), completing 25 miles of unbroken outcrop from the Elands River. From this point to Breedt's Nek this dyke is only seen at the surface at long intervals.

Dyke No. 2, on the other hand, is continuous from Breedt's Nek to Beestekraal (286), where it forms the topmost ridge of a considerable range. From that farm to the Elands River it occurs in disconnected outcrops.

The remaining dykes vary somewhat in character. They are finer-grained and not porphyritic. Some are remarkable in the fact that quartz occurs interstitially. This unusual association of quartz with nepheline is interesting, and a similar occurrence was noted by Mr. Kynaston in a rock from near Horn's Nek in the Magaliesberg.†

7. Faulting.

The most noticeable fault in the area is that described in the Annual Report of the Geological Survey for 1906.‡ It enters the area dealt with in the present report in the neighbourhood of Oliphants Nek, which is practically the apex of the obtuse angle described by the Magaliesberg Quartzites in the general change of strike of the Transvaal System in this neighbourhood. Owing to the change in the direction of the strike of the Pretoria Series, which takes place in the neighbourhood of Oliphants Nek, this fault, after entering the Magaliesberg Quartzites from the south-east partakes more of the nature of a strike fault, and is thus more difficult to follow on the northern side of the escarpment. Its presence, however, is made probable by the existence of the double-fold consisting of a syncline followed by an anticline which is developed along the Magaliesberg Quartzites from the neighbourhood of Onderstepoort to within a few miles of Breedt's Nek. This syncline and anticline are distinct, and noticeable on the downthrow side of the fault on the farms Olifantspoort (253) and Boschfontein (193), and a careful examination of the quartzites to the north-west along the continuation of the line of fault reveals the fact that along the northern portion of the common boundary of Rietvlei (824), and Baviaanskrans (288), the continuation of the anticline can be clearly observed, while the syncline is well developed on the farm Rietvlei, extending along the bed of the spruit which traverses that farm on to Baviaanskranz, where its northern arm gradually disappears, giving place to hills formed of diabase. Thus

* Reports of the Geol. Survey for 1905, p. 76; and 1906, p. 122.

† "On Certain Rocks associated with the Norites and Granites of Central Transvaal," Trans. Geol. Soc., S.A., vol. viii, p. 61.

‡ Annual Report Geol. Survey for 1906, p. 122.

it is clear that the apparent lateral displacement produced in the Magaliesberg Quartzites by this fault is about 3½ miles, whereas the apparent displacement of the Daspoort Quartzites is 2½ miles.* Thus the effect of the fault diminishes in intensity from the Magaliesberg in a south-east direction. Very few data are available for the further tracing of its outcrop north-west of the farm Baviaanskranz (288), the probability being, however, that it passes through the farm Boschdal (634), and along the junction between the Norite and the Diabase to the west of the town of Rustenburg.

The continuity of the Magaliesberg is broken at Onderstepoort, but the outcrop of the shale and diabase horizons in the Selons River valley are so infrequent as to render the tracing of the dislocation impossible without further data being obtained from the country on the northern side of the Elands River.

8. Economic Geology.

(a) *Water-Supply.*

The question as to the source from which the numerous springs rising towards the crest of the Magaliesberg dip-slope derive their supplies is one of great interest, as it involves the consideration of geological questions connected with the Transvaal System and Bushveld Plutonic Series, and their mutual relations, which at present are still largely a matter of conjecture. The most important springs to be considered are those which form the head waters of the Sterkstroom. They consist of six main springs rising towards the crest of the Magaliesberg, east and west of Breedt's Nek. Mr. Karlsen, Hydrographic Surveyor to the Irrigation Department, estimates† the total yield of these six springs at 26·20 cubic feet per second, or 14,100,000 gallons per day, and this flow represents a catchment area of 141 square miles, taking 100,000 gallons per square mile as the average yield for the Crocodile River basin.

It is obvious that no such catchment exists along the summit of the Magaliesberg. Moreover, the dip of the Magaliesberg Quartzites being towards the north, as is also the general fall of the country, consequently any water following the horizon of these quartzites, and being prevented from escaping downwards by the underlying shales, would tend to flow away from the Magaliesberg and not towards it; that is to say, the underground flow of water would be in the same direction as the surface flow, away from the outcrops of the Transvaal System and towards the Bushveld.

To the south of the Magaliesberg lie the lower members of the Transvaal System, including the great water-carrier of the country, the Dolomite formation. At the same time the general level of the country rises to the south until the elevated portion of the High Veld, occupied by the Dolomite, is at a considerably higher elevation than the slopes of the Magaliesberg where these springs issue. It is thus possible that the water issuing from these springs may have its origin in the Dolomite formation, and pass in the Dolomite under the low-lying valley to the north of the Magaliesberg, finally taking advantage of vertical joints or transverse dykes to reappear at the surface; or possibly minor faulting may be responsible for providing an outlet. This is the principle of the syphon on a large scale, and has been proved to apply to springs in many other parts of the world. The lack of accurate knowledge of the mutual positions of the Transvaal System and the Bushveld Plutonic Series in the area immediately to the north of the Magaliesberg, and of the extent of the former beneath the Red Granite, renders a definite statement premature. It is, however, certain that at some place in the area the Transvaal System was broken through by the igneous masses welling up from below, and that consequently by following the dip from the Magaliesberg, one would eventually come to the broken edges of the Transvaal System abutting against the igneous rock. At this line of contact water following the Dolomite horizon would be dammed back, and being under pressure would make use of vertical joints and dislocations, and invade the upper horizons of the system. It could only find an exit by following the sedimentary formations up along the dip until they emerged from beneath the overlying igneous rock, or until joints and fissures gave it access to the surface. The presence of vertical fissures and joints in these quartzites renders the circulation of the water quite possible.

Mr. A. Karlsen points out the possible connection between the reputed increase of the flow of the Sterkwater source of the Sterkstroom, and the decrease in the yield of the Steenkopjes Spring which supplies the Blauwbank River. As, however, these springs have not been sufficiently gauged, it is impossible to speak with any certainty regarding the increases or decreases of their flow. Analyses are being made of the water issuing from the springs to the north of the Magaliesberg with a view to instituting a comparison with the water

* Annual Report of Geol. Survey for 1906, p. 122.

† For the estimates of the yield of these springs, the writer is indebted to a report by Mr. A. Karlsen, kindly supplied by the Chief Engineer of Irrigation.

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of the Dolomite area. The dyke which cuts the Transvaal System at right angles to its strike, and which can be traced from Breedt's Nek in the Magaliesberg for many miles to the south, is probably an important factor in the underground drainage system.

Strong streams rise on the farm Rietvlei (824), namely, the Rustenburg Dorpspruit, and the stream flowing through Waterkloof (4). Both these carry a plentiful flow of water. The local catchment area consists of a wide and shallow depression formed by a syncline of quartzite beds of an area of 8 square miles at most. This syncline forms the greater portion of the farm Rietvlei. Mr. Karlsen estimates the yield of these two springs at 2,400,000 gallons per day, which would require a catchment area of 24 square miles. Consequently these springs must have sources of supply other than those which can be accounted for locally. At the same time local information obtained shows that their yield is subject to variation after continuous local rains, so that the local catchment area certainly supplies a considerable part of the flow.

Irrigated crops are raised along the whole course of the Sterkstroom as far as Berseba Mission Station, the supply of water being abundant in its higher reaches, while the Hex River in the district under review is utilised only on certain farms, the steepness of its banks probably rendering only on certain farms the utilisation of its water a more difficult problem.

(*b*) *Ore Deposits.*

*Chromite.**—Along a zone in the lower portion of the norite, numerous outcrops of chrome-iron ore occur. These are usually to be found along a line which is approximately parallel to the junction between the norite and the underlying diabase. The ore is compact and granular, of an iron-black colour, and when weathered, exceedingly friable. The chemical composition of the Kroonendal ore, as determined by Dr. J. Loevy, of Berlin (kindly supplied by H. Merensky, Esq.), is as follows:—

Cr_2O_3	36·16 per cent. (=24·74 per cent. chromium).
Fe	41·35 „
Al_2O_3	9·26 „
MgO	5·91 „
CaO	2·10 „
SiO_2	3·08 „
Silver	·0012 „
Platinum	trace.

It is usually associated with basic varieties of norite, in which hypersthene is the predominant mineral. Occasionally this becomes a pyroxenite showing no felspar and consisting entirely of hypersthene.

The best outcrops in this area are to be found on the farms Kroonendal (177) and Arnoldstad to the south-west of Rustenburg. On Kroonendal good outcrops occur in the bed of the most northerly of the spruits on the farm. About 200 yards below the point where the road to the north-east crosses this spruit, and in the bed of the stream, two bands of chromite occur showing the relationship of the ore to the country rock very plainly. The upper band has a thickness of from 6 to 7 inches, and the lower measures about 12 inches across. They are separated by a basic norite of similar character to that which occurs both above and below the ore deposit. In the immediate neighbourhood of the main ore bands chromite is found in grains in the norite, but the transition from chromite to norite takes place within extremely narrow limits. Plate VII, Fig 2, illustrates the outcrop just described.

Owing to the rounded hummocky character of the stream-bed, and also to the variations of dip, some of the outcrops present the appearance of concentric rings and rounded lumps, which give the impression of a spheroidal segregation of ore. This, however, is only apparent.

On the farm Arnoldstad an outcrop occurs about 200 yards W.S.W. of the iron wagon bridge across the Hex River. It takes the form of a low ridge which crosses the side road leading to Waterkloof. The relationship to the norite is not apparent in this outcrop, as the surface soil and boulders obscure the contact. Immediately overlying the chromite to the north a hypersthene-pyroxenite is found, which marks a point of difference between this outcrop and that upon Kroonendal just described. Further outcrops occur on the farms Boschfontein (489) and Waterval (544), while on Brakspruit (393) and Boschkopje (685) fragments are to be observed on the surface. From the strike of the outcrops when determinable it would appear that

* See also Hall and Humphrey, "On the Occurrence of Chromite Deposits along the southern and eastern margins of the Bushveld Plutonic Complex," Trans. Geol. Soc., S.A., vol. xi.

the chromite occurs at two horizons striking practically parallel to each other. Their outcrops are separated from each other by a surface distance of about 2 miles. If this is the case the Kroonendal outcrops just described belong to the upper horizon, while that on Arnoldstad belongs to the lower.

It is interesting to note that the only authentic occurrence of platinum so far found *in situ* occurs in this type of rock in the Ural Mountains, viz., associated with chromite in serpentine and basic igneous rocks. In view of the fact that platinum has been reported in assays of chromite from this district, this point should be borne in mind when washing any of the sands and gravels of streams which have traversed the norite zone. Assays of chromite from this area made in the laboratory of the Geological Survey failed to reveal any platinum, but in view of the wide distribution of this horizon in the Transvaal, evidence from one locality only is not conclusive. The writer is indebted to Mr. A. von Dessauer for information and assistance in locating some of the above outcrops.

Magnetic Iron ore.—The magnetite bands traversing the norite in this area call for no special attention. They have been repeatedly described, and the occurrences in this locality differ in no respect from those occurring further east.

Occasional isolated kopjes occur scattered through the norite area, which consist almost entirely of an impure magnetite.

Hæmatite.—This ore occurs cropping out in large boulders on the farm Tweerivier (823) on the line of contact between the Dolomite and the granite. It is slightly magnetic and probably represents a composite ore.

Gold.—Alluvial gold has been found on the farms Commissie Drift (300) and Boschfontein (193) but no work is being done there at present.

GOLDEN GATE HIGHLANDS

VII.

REPORT

ON A PRELIMINARY EXAMINATION

OF THE CASSITERITE DEPOSITS

OF ZAAIPLAATS

AND SOME OF THE NEIGHBOURING FARMS,

IN THE WATERBERG DISTRICT.

By H. KYNASTON (*Director*).

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VII.—REPORT ON A PRELIMINARY EXAMINATION OF THE CASSITERITE DEPOSITS OF ZAAIPLAATS, AND SOME OF THE NEIGHBOURING FARMS, IN THE WATERBERG DISTRICT.

By H. Kynaston (*Director*).

1. Introductory.

The following report is the result of a preliminary examination of the cassiterite deposits of Zaaiplaats (1328) and some of the adjacent farms in the Waterberg District, carried out during the latter part of November and early part of December, 1907. As only a limited time was available for the examination of these interesting and important deposits, it is proposed here to give a short general account of them and their geological relationships, preliminary to a more detailed study which will be combined with a systematic geological survey of the area to be undertaken during 1908.

2. General Physical and Geological Features of the Area.

The farm Zaaiplaats lies about twenty-two miles west-north-west of Potgietersrust, and is situated in the mountainous belt of country which separates the Magalaquene Valley from that of the Sterk River. The country between these two rivers here forms a range of hills, steep and sharply defined on the east and north-east, but sloping more gradually on the west towards the Sterk River, beyond which it is succeeded by the extensive and elevated tract of country known as the Palala Plateau.

The general geological features of this part of the Waterberg District have been briefly described by Dr. Molengraaff in his Report as State Geologist for 1898. The mountainous belt between the Sterk and Magalaquene Rivers consists in its more elevated portions of Red Granite—the northerly extension of the Red Granite of the Bushveld. In this part of the country, however, in contrast to its mode of occurrence in the Bushveld to the south, the Red Granite forms elevated and rugged country, its outcrop forming a wide belt extending from the junction of the Sterk and Magalaquene Valleys south-eastwards towards Potgietersrust, and thence gradually bending round in a general south-westerly direction towards Nylstroom. Viewed from the comparatively low-lying country further east or south-east, this range of granite hills forms one of the most conspicuous features of the district.

On its east and north-east sides the Red Granite is followed by norite and other basic rocks, such as are usually associated with it in other parts of the country, and these again, in the neighbourhood of Potgietersrust, by rocks belonging to the Transvaal System. To the south-east, however, the granite appears to terminate somewhat abruptly, and is succeeded by the much younger amygdaloidal basalts, which cover the extensive plains of the Springbok Flats.

On the western or inner side of the semi-circle of granite hills the Red Granite is succeeded by the felsites of the Lower Waterberg, which are well exposed along that portion of the Sterk River Valley lying west-north-west of Potgietersrust, and these, in turn, pass westwards beneath the sandstones and conglomerates, which gradually merge into the main mass of the Upper Waterberg rocks of the Palala Plateau. Further south, however, to the west of Moorddrift, the Upper Waterberg sandstones may be found resting directly upon the granite, apparently without any intervening representative of the lower division of the system.

The general structure of the area would appear to constitute a portion of a broad, though comparatively shallow, synclinal basin, with an outer rim of igneous rocks dipping gently towards and passing beneath a huge central plateau of sedimentary strata.

The farm Zaaiplaats is situated partly upon the Red Granite, and partly upon the Felsites, the line of junction between the two, though not very clearly defined, passing in a general S.S.E. direction obliquely across the south-western portion of the farm, the north-eastern portion, with the exception of a few basic dykes, consisting of Red Granite.

3. The Red Granite.

The Red Granite of Zaaiplaats and the adjoining farms is composed, on the whole, of similar petrological types and varieties to those occurring in the Bushveld further south. The chief difference between the igneous masses of the two areas lies in the fact that the granite of this more northerly and more hilly area shows a more definite, or perhaps more easily recognised, order in the disposition of its constituent varieties than is generally noticeable in that of the Bushveld. This is due to the fact that the granitic belt here exposed shows, as a whole, a more distinct general inclination or dip, which serves to bring out more clearly the different varieties or phases of intrusion as they succeed one another. In fact, in several parts of the granite area, especially where finer-grained varieties predominate, an appearance resembling stratification is peculiarly striking, the planes of what may, perhaps, be termed pseudo-bedding having usually a gentle inclination of from 10 to 15 degrees in a general westerly direction.

The relation of the different varieties to one another would appear, on the whole, to be that of successive sheets, the variation throughout the whole mass being of a vertical rather than a lateral type.

Thus, commencing on the north-eastern or escarpment side of the range of hills which forms the south-western boundary of the Magalaquene Valley, we find a coarse, massive pinkish granite, identical with that so characteristic of large areas of the Bushveld, with its principal constituents, quartz, red felspar, and a little biotite, clearly distinguishable to the unaided eye. Followed upwards into the hilly ground, this granite is found exposed in huge, bald, hummocky masses, which give it a very characteristic appearance. This coarse type forms a well-marked belt, trending roughly parallel to the margin of the norite, and it is with this coarse granite that the peculiar cassiterite-bearing pipes of Zaaiplaats are associated.

This granite is admirably exposed over the higher parts of Messrs. Maggs & Munro's claims on the north-eastern portion of Zaaiplaats, showing enormous bare rounded masses of rock, alternating with steep-sided gullies and irregular depressions. Small basin-shaped hollows and smooth-sided grooves are also common over the surface, and due to surface disintegration mostly acting along the main lines of jointing. One such groove or hollow, coinciding with a joint plane, shows somewhat unusual features. Situated on the upper part of a bare ridge, it forms a narrow, elongated hollow, about 30 feet in maximum depth and from 20 to 30 feet in breadth, filled with sandy and gravelly material, containing at the bottom some scattered well-rounded boulders of sandstone and quartzite, the origin of which is not easy to satisfactorily account for under the present physical conditions of the country. The granite in this neighbourhood is also sometimes traversed by small fine-grained aplitic bands or veins.

The coarse granite is apparently overlain on Zaaiplaats by an extensive belt of a finer-grained type, which occupies all the higher ground in the immediate neighbourhood of the coarser rock. It forms the high ridge on which is situated the north-east corner beacon of the farm, whence it is continued to the north-west, and thence south-west and southwards, so as to form the small ridge immediately above the Government camp, while the small valley between this and the main ridge on the northern boundary of the farm is occupied mainly by the coarse granite. This finer-grained type is usually easily recognised by its rather bright red colour, due to the high proportion of red felspar which it contains, though occasionally it may assume a more greyish colour. Quartz, though not always conspicuous to the unaided eye, is seen under the microscope [A395] to be well developed, but occurs almost exclusively as a micrographic intergrowth with the felspar, so that, strictly speaking, the rock should be termed a granophyre.

This red granophyre, as the rock may more appropriately be termed, is separated from the coarse granite by a well-marked band, or sometimes several bands, of vein quartz and coarse pegmatite, inclined at a low angle in a general westerly direction in conformity with the general inclination of the main mass of the granite of this area. This band is of remarkable persistence, and may be followed from the north-eastern portion of Zaaiplaats south-eastwards into the southern corner of Groenfontein (871).

Between this pegmatite and the main mass of the coarse granite on Zaaiplaats there is a comparatively narrow zone comprising several varieties of finer-grained types, apparently dipping beneath the pegmatite. This zone further appears to widen out as one proceeds eastwards, and is represented on Groenfontein by a zone, about a quarter of a mile in width, of a pinkish medium to fine-grained granite. It is in association with this type that the stanniferous pipes on Groenfontein occur. The Groenfontein rock consists for the most part of a mixture of quartz and felspar, while a ferro-magnesian element is often entirely absent. Under the microscope the rock shows a somewhat characteristic appearance, which distinguishes it from the other fine-grained varieties, the structure being rather of the granulitic than of the granophyric type [A409 and 426]. The quartz appears to stand out from the felspar in rounded and angular grains, usually enclosed by the felspar, though occasionally small grains of felspar are seen to be enclosed by the quartz. This is probably

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due to more or less simultaneous crystallisation of the two minerals, resulting in an imperfectly developed micrographic structure. The rock also contains occasional flakes of altered biotite, and, in the neighbourhood of the cassiterite pipes, sericitic mica and fluorite.

Between the pegmatite band and the typical coarse granite on Zaaiplaats several fine-grained modifications occur succeeding one another in bands or sheets, showing the general inclination already alluded to above, the general arrangement often bearing a marked resemblance to that of bedded strata. Several of the cassiterite " chutes " or lenses, worked on the reserved portion of the farm, occur among these finer-grained bands, the resulting apparent great variety of granitic rocks thus found in association with and impregnated with cassiterite, being at first sight a somewhat puzzling feature, but to a great extent the result of varying degrees of alteration.

Thus, at the No. 2 workings, these fine-grained rocks show both granophyric and granulitic varieties, the latter perhaps predominating and more or less resembling the Groenfontein type already noticed, the former being distinguished by its more felspathic appearance. In the immediate neighbourhood of the cassiterite deposits both types often pass into a dark greyish or greenish mass, consisting largely of quartz embedded in a groundmass of pale yellowish green sericite, developed at the expense of the felspar, while small quantities of fluorite and occasionally dark greenish tourmaline are also common [A 367, *a*, *b*, *c*, and *d*; 368, *a*, *b*, and *c*; 369, *a* and *b*]. The alteration, however, of these granites will be referred to again in connection with the cassiterite.

The different varieties of granite above noticed together constitute the bulk of the Red Granite series of this area. They probably do not represent distinct intrusions, separated by any very marked interval of time, but for the most part may be regarded as modifications of the normal type, the textural and structural variations being due to differences in the conditions of consolidation. Possibly the red granophyre, which overlies the pegmatite zone, may represent a slightly later phase of the main intrusion, as is probably the case with similar granophyres occurring between the norite and the coarse red granite along the southern margin of the Bushveld. The fine-grained acid bands, occasionally found intersecting the coarse granite, may also belong to a slightly later stage of the main intrusion, but are more of the nature of contemporaneous veins than later dykes. True dykes are also sometimes found cutting across the granite, with a general N.E. and S.W. trend, those so far met with, however, consisting of a decidedly basic rock composed mainly of plagioclase and augite [A 394].

The general behaviour of the granite mass in this area and the general disposition and bedded appearance of its principal varieties lends support to the theory of a laccolitic mode of occurrence for the intrusion, the mass, as a whole, appearing to dip beneath the felsites and sandstones of the Waterberg System on the west. The coarse red granite, on this supposition, would constitute the main body of the laccolite, the norite, on the north-east, representing the lowest or earliest phase of the intrusion in the form of a basic differentiation from the parent magma, while the granophyre lying between the normal granite and the Waterberg felsites would have formed the latest phase.

4. General Distribution and Mode of Occurrence of the Cassiterite.

The principal deposits of cassiterite occurring on Zaaiplaats and the adjoining farms are found along a fairly well defined belt or zone in the granite, extending from the north-eastern corner of Zaaiplaats in a general south-easterly direction, across the northern corner of Roodepoort and the southern portion of Groenfontein, thence trending in a slightly more southerly direction across the west corner of Sterkwater into the northern portion of Solomon's Temple. The results, moreover, of recent prospecting work would appear to indicate a further extension of the belt both to the north and south. The width of this tin-bearing zone varies considerably, the average being probably about a quarter of a mile. On Roodepoort, Groenfontein, and Sterkwater, it would probably not exceed 1,500 feet. On its south-west side it is limited by the line of quartz and pegmatite veins already referred to, though on the north-east it does not appear to be sharply defined by any very well marked or conspicuous geological boundary.

Throughout this zone the principal and most important cassiterite deposits are found in the form of peculiar elongated cylindrical pipes or pipe-veins. No such occurrences have been found to the south-west of, or above, the pegmatite line, and they become smaller and less frequent to the north-east, their place being taken, especially on Groenfontein and Roodepoort, by small pockets or " eyes " of tourmaline, which carry little or no tin, and gradually die out altogether. The section given on Fig. 5 shows the position of the tin-bearing belt on Roodepoort and Groenfontein with regard to the three principal phases of the Red Granite,

the stanniferous portion here coinciding roughly with the zone of the medium-grained granulitic type, already described, lying between the massive coarse rock and the red Granophyre.

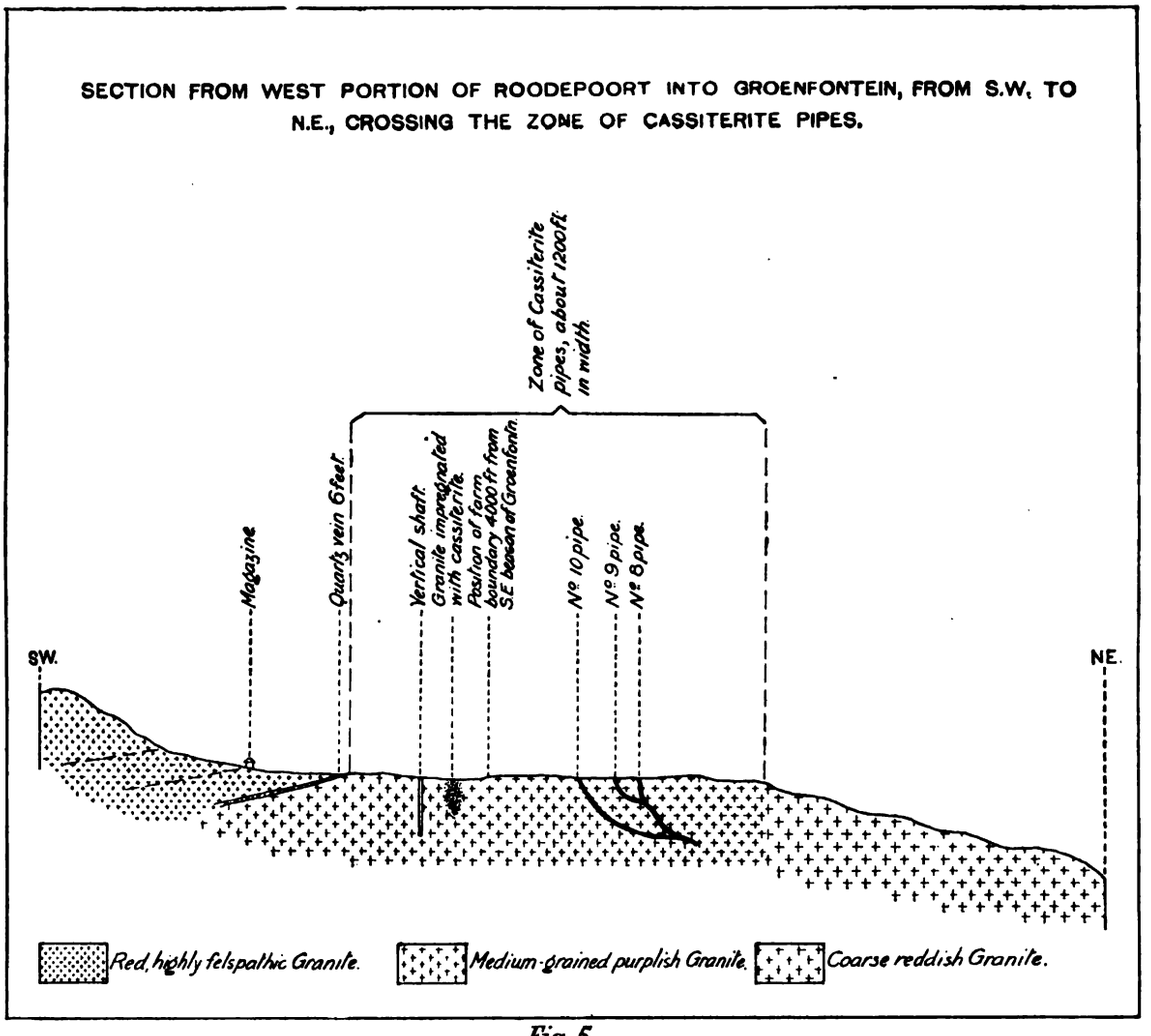
SECTION FROM WEST PORTION OF ROODEPOORT INTO GROENFONTEIN, FROM S.W. TO N.E., CROSSING THE ZONE OF CASSITERITE PIPES.
Zone of Cassiterite pipes, about 1200ft. in width.
Magazine
Quartz vein 6 feet.
Vertical shaft.
Granite impregnated with cassiterite.
Position of form boundary 4000 ft. from S.E. beacon of Groenfontein.
No. 10 pipe.
No. 9 pipe.
No. 8 pipe.
SW.
NE.
Red, highly felspathic Granite.
Medium-grained purplish Granite.
Coarse reddish Granite.

Fig. 5

On Zaaiplaats the portion of the tin-belt carrying the true pipe form of deposit is practically restricted to Messrs. Maggs & Munro's claims near the north-eastern corner of the farm, the pipes appearing in the coarse granite in groups distributed principally over the steep slopes, which overlook the small narrow valley, trending north-east towards the western portion of Groenfontein. Passing on to the Government portion of the farm bordering Messrs. Maggs & Munro's claims on the north-west and west, the cassiterite occurs rather as more or less lenticular deposits than as true pipes, following the general inclination of the country rock or sometimes associated with fissures in the granite, while various intermediate forms of deposit may be found between the steeply inclined chimneys or pipes and gently inclined ore-courses. It would appear, as a general rule, that the pipe form follows the coarse massive and homogeneous granite, while as one enters the zone of the finer-grained varieties, the deposition of the cassiterite has tended to follow the divisional planes between the successive sheets of these varieties, though at the same time it has often taken advantage of more steeply inclined joint-planes and fissures. Finally, on reaching the pegmatite bands and the overlying red granophyre, all well defined deposits of tin ore appear to die out, only occasional small patches and stringers of cassiterite crystals occurring in association with the pegmatite.

5. The Cassiterite Deposits on Zaaiplaats.

As already pointed out, the most important deposits on Zaaiplaats are found on Messrs. Maggs and Munro's claims in the form of roughly cylindrical and usually highly inclined pipes. Various terms have been

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used to designate this class of deposit in this area, such as chute (or shoot), chimney, lens, etc., but the term pipe has now come into more general use and would appear to be the most appropriate. This term and the term pipe-vein are both employed in describing analogous occurrences of deposit of cassiterite and bismuth ores by the Government Geologist of New South Wales. For the ore-deposits worked by the Government on the reserved portion of Zaaiplaats the term chute, employed in a somewhat broad sense, would appear to be more applicable than the designation lens, since these deposits, though frequently lenticular in transverse section, very rarely constitute lenticular shaped bodies, and are frequently connected with one or more definite lines of fissure in the granite. Their inclination is often gentler and more uniform than that of the pipes, but this character varies so much in both cases, that it cannot be said to constitute a very distinctive feature of either type of occurrence.

The Pipes.

The pipes are roughly circular, oval, or elliptical in section, of all sizes, and are directed into the side of the hill in a general north-westerly direction, though the actual direction is subject to frequent changes, and is by no means constant in the same pipe.

A general view of the hilly ground where the pipes are situated gives the impression that they occur roughly in rows or tiers one above the other. Thus, on the lower slope of the hill, immediately above the road leading up to the camp, about twelve pipes have been located within an area about 300 yards square, while above this is seen another smaller group, arranged more or less in line, roughly parallel to those below. The significance, however, of this mode of arrangement and its possible connection with planes of weakness in the granite requires further investigation.

About twenty pipes had been located at the time of the writer's visit, the largest of which showed a face of about 8 or 9 feet in vertical diameter, by 4 or 5 feet in width. Occasionally, however, though not often, the width in cross-section may be greater than the height. They are well defined and sharply marked off from the surrounding rock, the passage from the normal coarse granite to the highly altered body of the pipe being exceedingly rapid.

The granite often becomes of a redder colour than usual within a few inches of the margin of a pipe, owing no doubt to the gradual alteration of the felspars, and this red zone is sometimes succeeded by an aureole of tourmaline-quartz rock, forming a casing to the actual cassiterite-bearing portion of the pipe (see Fig. 6). In the majority of the Zaaiplaats pipes, however, the tourmaline border is entirely absent.

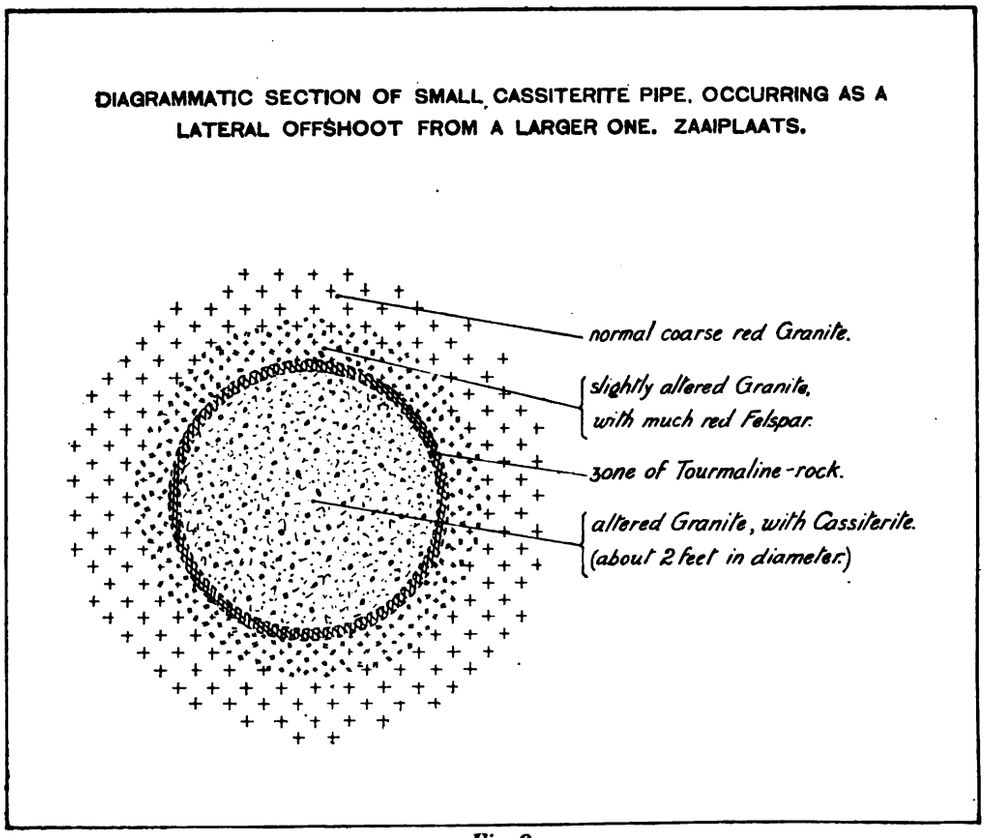
DIAGRAMMATIC SECTION OF SMALL CASSITERITE PIPE, OCCURRING AS A LATERAL OFFSHOOT FROM A LARGER ONE. ZAAIPLAATS.
normal coarse red Granite.
slightly altered Granite, with much red Felspar.
zone of Tourmaline-rock.
altered Granite, with Cassiterite. (about 2 feet in diameter.)

Fig. 6

As a rule, each pipe appears to behave quite independently of its neighbour, and there is no evidence that would indicate that they constitute ramifications from any central body or main trunk. Occasionally, however, two or three neighbouring pipes, while quite distinct at the surface, are found to join company in depth and form a single cylindrical ore-body; and sometimes, on the other hand, two pipes, while distinct from each other in depth, may unite at or near the surface. On the whole, a pipe will maintain a general uniformity of dimension for a considerable distance, though, of course, there may be frequent irregularities, bulges, contractions, etc., along its course. In one case, however, a pipe was found to contract to a narrow vertical body with a wide bulging portion below. It then turned sharply at right angles to its normal direction, which, however, it reassumed after a short distance and then expanded again to its original proportions. The sudden change in direction and shape was no doubt caused by a temporary diversion along a line of fissure or joint. Generally speaking, the pipes are at first highly inclined, sometimes vertical, and then assume a more gentle angle of inclination, and are often approximately horizontal along part of their course. Thus No. 3 pipe descends vertically for the first 33 feet from the surface and then rapidly becomes almost horizontal, in which position it measures about 4 feet 6 inches in vertical diameter. At the end of November of last year one of the larger pipes had been followed for 230 feet on the incline, though later information gives the maximum distance reached in June, 1908, as about 320 feet, at which point no marked change could be detected in any of its more important features.

The pipes do not appear to be connected with any intrusions in the granite, nor apparently with any readily detected lines of fissure or faulting, though there is probably in many cases some connection with joint planes.

Owing to the frequent variations in these deposits, no description will apply equally to each occurrence, each pipe, both as regards behaviour and constitution having individual characters of its own, and no two being exactly alike.

Composition of the pipes.

Broadly speaking, the pipes may be described as elongated cylindrical bodies of highly altered granite impregnated with cassiterite. The cassiterite, however, is scarcely ever evenly distributed throughout the matrix, but is almost invariably more concentrated towards the periphery, the richest deposit being frequently found along the lower or footwall portion of the pipe. In the central portion the cassiterite crystals become less frequent and more scattered, and are often absent altogether. The very rich marginal portions sometimes show over 70 per cent of cassiterite.

The matrix of the cassiterite, although simply representing altered granite, varies considerably in appearance and composition, according to the degree of alteration and replacement which the constituent minerals of the normal rock have undergone. Very commonly, especially in the richer types, the matrix consists of a greenish substance, varying from a pale greyish green to almost black, and possessing a homogeneous appearance to the unaided eye. In examining, however, the different portions of various pipes every gradation can be found between this type of rock and an apparently unaltered type, in which the quartz and felspar of the original granite can be easily recognised. Even in the more highly altered phases it is common to find small patches of the original red felspar comparatively unaltered, while the passage from the unaltered granite of the pipe wall into the extreme phase of greenish alteration product of the central portion can often be clearly seen in cross-sections of some of the pipes. The highly altered matrix may sometimes appear in irregular patches, or at other times extend almost completely across the pipe. In one case this highly altered material is in an exceedingly loose, soft, and disintegrated condition, and so can be extracted with a minimum of labour.

In some cases, on the other hand, a very different type of matrix is met with which is remarkably hard and compact, and of a more pinkish or sometimes greyish colour. This type is the result of secondary silicification. It is, however, more characteristic of the Roodepoort-Groenfontein pipes, and is only occasionally found in those of Zaaiplaats, and in these latter often only partially developed. There are a few other cases again in which small portions of the altered granitic matrix has been partially replaced by secondary calcite.

Petrological characters.

So far as the general petrological examination of the pipes has proceeded, the common greenish matrix usually resolves itself under the microscope into a somewhat coarse aggregate of turbid felspar, partly still recognisable as plagioclase, with a little quartz, and patches of sericite. Sericite, however, is sometimes apparently absent, a specimen from No. 4 pipe showing coarse crystals of cassiterite in a matrix of large

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altered plagioclase crystals and some coarse secondary quartz, the green colour of the rock being due to the finely disseminated cloudy matter in the felspar. The secondary quartz partially replaces the felspar [A 386 *a*]. Another portion of the same pipe from nearer the centre shows patches of greenish yellow, finely divided sericite between the felspars [A 386 *b*].

Secondary silicification is well seen in the matrix of the upper or hanging-wall portion of pipe No. 3A, a section under the microscope [A 380] showing coarse cassiterite crystals surrounded by a very finely granular siliceous groundmass, with an occasional large crystal of secondary quartz associated with small tourmaline needles. In a portion of another pipe the tin occurs in coarse calcite and secondary quartz [390].

The tourmaline rock, occasionally found surrounding the Zaaiplaats pipes, consists of needles of greenish tourmaline, arranged in radial aggregates, and coarse secondary interlocking crystals of quartz [A 378 *a*], while sericite and cassiterite make their appearance on the inner margin of the tourmaline zone [A 378 *b*].

The Chutes on Zaaiplaats.

The deposits worked on the Government portion of Zaaiplaats are usually inclined approximately west 16 degrees south, at angles varying from 12 degrees to nearly 45 degrees, the lower angles of dip apparently coinciding with the general inclination of the finer-grained bands of granite in which they occur, and which succeeds the coarse rock which contains the true pipes. The inclination, both in direction and degree, and the dimensions and shape of one and the same ore-body often vary considerably. Thus in No. 1 workings the ore-bearing rock dips at first at nearly 45 degrees, and is about 18 inches in thickness; afterwards, however, it shows various changes, both of inclination and thickness. No. 2 chute after being followed for about 20 feet, with an average width of 5 or 6 feet, apparently died out. No. 6 showed a well defined body of altered stanniferous granite, carrying high grade ore, dipping at an angle of 30 degrees for a distance of 30 feet, when its direction took a sharp turn through 45 degrees. Recently a considerable amount of further work has been done on this and other deposits in the same neighbourhood, a description of which must be deferred to a later report.

The granite associated with these deposits consists of medium to fine-grained granophyric and granulitic varieties, both of which can be readily detected in the altered matrix of the cassiterite. As in the pipes, the cassiterite-bearing portion is often of a dark greenish to yellowish colour, though the cassiterite is usually somewhat more sparingly developed. There is also often a sudden change from apparently unaffected to highly altered rock.

The alteration is here evidently mainly due to the development of sericite at the expense of the felspar. A hand specimen of the more altered dark rock from No. 2 shows remains of original quartz and red felspar, with sericite and scattered crystals of cassiterite, pyrites, and small patches of mispickel. In some specimens a little calcite is also present, and small patches of copper carbonates, and fluorite. Sections under the microscope often have a very characteristic appearance consisting mainly of numerous quartz grains, separated by partially altered felspar and greenish yellow sericite, or surrounded entirely by a sericite matrix with occasional grains of fluorite [A 367–369 and 371]. This represents the granulitic structural variety of the fine-grained granites, while in others the granophyric structure can sometimes still be recognised, though often obscured in the more altered phases. The sericite is sometimes in relatively coarse platy aggregates, and sometimes in a finely divided condition, and it is to the presence of this mineral that the dark colour of the altered rock is evidently due.

6. The Pipes on Roodepoort and Groenfontein.

On the portion of Roodepoort adjoining the north-eastern portion of Zaaiplaats, the coarse granite, extending from the latter, forms prominent ridges, the weathered surface of the rock standing out in characteristic, bald, hummocky masses. On these are a considerable number of small and medium sized pipes, inclined mostly to the north and north-west, sometimes occurring in groups, and frequently showing a narrow tourmaline border. Some of these carry a high grade of ore.

From these ridges the general inclination of the granite, combined with the surface contour, carries the zone of pipes a short way to the south up the deep valley traversing Roodepoort from the south, and then east into Groenfontein. Here, however, the pipes are found in the medium grained granulitic type of granite already described, which succeeds the coarse type.

Altogether, on both farms, some fifty pipes have been located within the zone. They are often very large at the surface, and descend at first very steeply, often almost vertically, and then assume a more gentle inclination. The direction of inclination varies between west and north-north-east. They often branch or

fork towards the surface, two or three neighbouring pipes thus uniting at a short distance from the surface (see Fig. 5). In general behaviour they closely resemble those of Zaaiplaats, though some have been found eventually to pinch out at depths varying according to their size, the larger persisting to between 200 and 350 feet on the incline. These suddenly showed very rich deposits of cassiterite just before their apparent termination, the place of the tin-bearing rock being finally taken by a mass of tourmaline. Fig. 7 shows a diagrammatic transverse section of the average type of the pipe form of deposit in this locality.

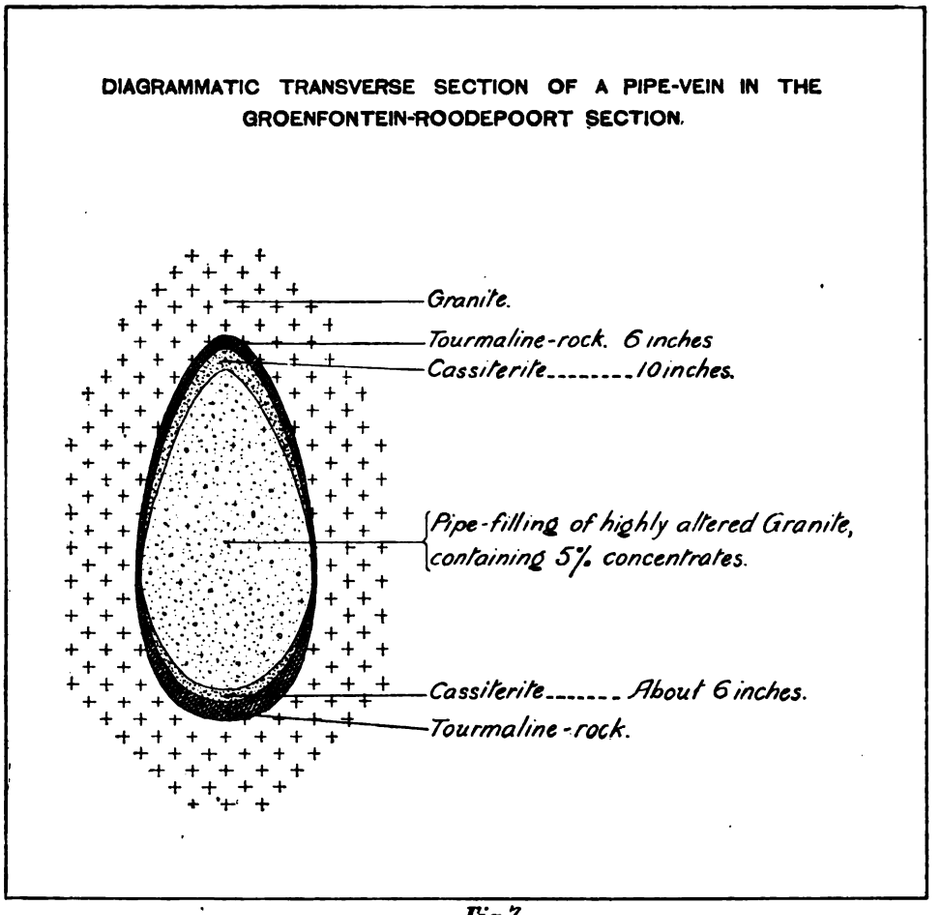
DIAGRAMMATIC TRANSVERSE SECTION OF A PIPE-VEIN IN THE GROENFONTEIN-ROODEPOORT SECTION.
Granite.
Tourmaline-rock. 6 inches
Cassiterite.....10 inches.
Pipe-filling of highly altered Granite, containing 5% concentrates.
Cassiterite..... About 6 inches.
Tourmaline-rock.

Fig. 7

The chief difference between the Groenfontein pipes and those of Zaaiplaats consists in the far more frequent occurrence of the tourmaline border in those of the former locality, and the common occurrence of secondary silicification of the pipe body; while, so far as present experience has gone, the larger pipes of Zaaiplaats have shown a relatively greater persistence in depth. No. 10 pipe on Groenfontein shows a good example of the resilicified matrix, the cassiterite crystals being embedded in a hard, compact, pale yellowish groundmass, which is seen under the microscope to consist of an exceedingly fine-grained aggregate of secondary quartz and sericite [A 412]. Another specimen from a portion of silicified pipe-matter consists of comparatively large secondary quartz individuals, in well formed crystals, in a groundmass of finely divided secondary quartz and sericite [A 414].

Small tourmaline pipes or pockets, often without any cassiterite, are also common along the northern portion of the zone, the tourmaline occurring in masses of closely crowded spheroidal bodies, made up of radiating needle-like crystals. The usual secondary quartz always accompanies the tourmaline. The central portion of some of these small tourmaline pipes is sometimes hollow, the cavity being lined by the projecting rounded surfaces of the tourmaline spheroids.

7. Other Modes of Occurrence.

In addition to the pipe form of deposit, one of the most interesting occurrences of cassiterite on Roodepoort consists in the deposition of coarse cassiterite in association with the massive quartz vein, which

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traverses the northern corner of the farm. The quartz vein is here about 6 feet in thickness and dips gently beneath the massive red granophyre, which overlies the cassiterite belt. The cassiterite is associated with its lower portion and occurs as three or four thin flat veins, from a quarter to one inch in thickness, lying partly along the lower surface of the quartz and in vertical cracks in it, and partly in the underlying granite. A portion also of the quartz vein consists of a well marked breccia, carrying large crystals of cassiterite, fragments of quartz, patches of fluorite and sericite in a cherty matrix. The cassiterite is often in bunches and aggregates of large well formed crystals up to nearly half an inch in diameter. In one case it has replaced part of the quartz in a pegmatitic portion of the vein, the original graphic structure of which is now represented by narrow inter-penetrating bands of felspar and cassiterite. Small patches of coarse cassiterite are also sometimes found in the pegmatite on Zaaiplaats.

A narrow belt of granite impregnated, though not richly, with cassiterite, occurs a short distance south-west of No. 10 pipe, Groenfontein. Somewhat similar impregnations, apparently not directly connected with any pipe or fissure, also occur on Zaaiplaats. In these the granite only shows slight alteration. In one instance, on Messrs. Maggs & Munro's claims, a narrow band of ore-bearing rock was found about 12 inches in width and descending almost vertically, evidently being directly connected with one of the main lines of jointing in the granite, with whose direction it roughly coincides.

Other modes of occurrence and variations of the chute form of deposit already noticed have recently been opened up on Zaaiplaats, since the writer's visit, and these will be described in a later report.

8. Principal Minerals associated with the Cassiterite.

Probably the two commonest and most characteristic of the minerals associated with the cassiterite deposits of this area are *tourmaline* and *sericite*, both often taken as indicative of the probable presence of tin ore. Tourmaline, however, is frequently found in the absence of any trace of cassiterite, while rich deposits of cassiterite often occur in the absence of tourmaline, as is frequently the case on Messrs. Maggs & Munro's claims. Sericite also is of frequent occurrence in the only slightly altered phases of the granite, but is almost invariably present in some form or other in the tin-bearing rock. The two minerals differ somewhat in their mode of origin, the sericite being formed from the alteration of the felspars, while the tourmaline has been introduced together with the cassiterite and constitutes rather a mineral of replacement.

Secondary *quartz* invariably accompanies the tourmaline, and often forms almost the entire matrix of the cassiterite, having replaced the original granitic constituents of the ore body. It also forms a lining to vugs and drusy cavities.

Fluorite is characteristic of all phases of the altered granite and is allied to the tourmaline and secondary quartz in its mode of origin, though somewhat more widespread in its distribution.

Chlorite is sometimes present as an alteration product in the tin-bearing granite and pegmatite.

Calcite is also sometimes found replacing the granitic minerals, but is not common or characteristic.

Among the *metallic minerals* found in the tin-bearing pipes and chutes, *arsenical pyrites*, *copper ores*, and *iron pyrites* are the commonest, and occur usually as small scattered patches and crystals. Among the iron ores, in addition to pyrites, *micaceous iron ore* or *specularite* also sometimes occurs, and occasionally iron carbonate. As later introductions *galena* and *blende* occasionally appear in vugs in some of the pipes. From one of the pipes on Zaaiplaats a single specimen of *antimonite*, carrying gold, was obtained by Mr. Swinburne.

Wolframite occurs on Groenvlei, and *molybdenite* on Appingadam and Zaaiplaats, both associated with pegmatite, but the occurrences of these two minerals in this area have not yet been examined by the Geological Survey.

9. Comparison with other Areas.

In view of the somewhat unique character of the cylindrical pipe form of cassiterite deposit, hitherto not recorded elsewhere in South Africa or from the majority of the known tin mining districts of the world, it is of decided interest to note the occurrence of cassiterite deposits of a similar character under similar general geological conditions in New South Wales.

In "The Mineral Resources of New South Wales" (1901), the Government Geologist, Mr. G. F. Pittman, states (p. 141) that "stanniferous pipe-veins are a peculiar feature of both the Emmaville and Inverell Districts. They occur in granite as a rule and are cylindrical or oval in form. They sometimes dip at a considerable angle; at other times their course downwards is vertical." They differ, however, from the pipes of the Transvaal in being of smaller dimensions, and in the fact that they usually thin out at about 30 or 40 feet.

The cassiterite in them "occurs disseminated through a gangue of felspar, quartz, and chlorite." In one of the pipe-veins described, which strongly recalls some of those on Zaaiplaats, "the gangue consists of green felspar with crystals of cassiterite thickly disseminated through this." The average yield of the ore in this case is said to be 10 cwt. of tin-stone per ton.

In the same report a description is also given of the bismuth-bearing pipe-veins of Kingsgate and Pheasant Creek, situated in granite near its contact with claystones. These deposits show a still greater resemblance in behaviour, general character, and form to the cassiterite pipes of the Waterberg District than the pipe-veins previously noticed. The bismuth-bearing pipes also frequently "appear at the surface in several branches or heads, which at a depth of 30 or 40 feet unite into one main cylindrical ore-body." The maximum diameter of these pipes, however, is usually somewhat greater than that of the larger of the Waterberg cassiterite deposits.

The pipe or chimney form of cassiterite deposit is also known in the Malay States, where, however, it occurs, unlike those of the Transvaal, in limestone; moreover it appears somewhat doubtful whether the well known Lahat pipe is not in reality a cemented detrital deposit.*

10. Surface Indications of the Deposits.

The presence of tin deposits in this area has sometimes been detected during prospecting operations from the occurrence on the weathered surface of the granite of small roughly circular or oval depressions, about the surface of which small crystals of cassiterite, and occasionally tourmaline, may have been identified. Such hollows are doubtless due to the altered granite, which carries the cassiterite or its associated minerals, being usually liable to weather away more rapidly than the surrounding unaltered rock. The felspar also in the neighbourhood of cassiterite deposits often has a conspicuously red colour, and weathers more quickly than the unaltered mineral, and small patches of greenish yellow sericite and violet fluorite are common. It should be remembered, however, that neither the presence of fluorite or of tourmaline are by any means to be regarded as conclusive indications of the presence of cassiterite. Moreover, hollows in the granite, identical in appearance to those noticed above, are almost everywhere a common surface feature of the coarser granites, and may usually be said therefore to have no connection whatever with any form of mineralisation, merely as a rule indicating more rapid local weathering, sometimes along lines of jointing, or sometimes originating beneath small patches of moist vegetation.

Very few of the pipes were actually detected from such features, the majority having been located by carefully following up drifted or shed tin, found in the soil or sometimes in fragments of "float" rock, to its source of origin. Systematic sampling of the soil and superficial wash, occurring in the hollows and channels between the granite outcrops, has also been of very considerable assistance towards locating the outcrops or "eyes" of some of the ore-bodies. Drifted or shed tin is of common occurrence in certain parts of the area in the sandy soil filling the beds of small gullies and in deposits of washed down material occupying hollows in the granite and small runnels on the hill sides. In such places the crystals of cassiterite have often been detected after heavy rains.

11. General Remarks.

It has already been pointed out that a brief preliminary examination only has so far been undertaken of these interesting deposits. The present report does not profess to give more than a description of the mode of occurrence and general mineralogical characters of the cassiterite deposits, so far as these were accessible to examination towards the end of 1907, and it is obvious that the further development and prospecting work which has taken place in the area since that time will have rendered available much further information than it was possible to furnish in the present account. This, however, it is proposed to supplement at a later date by a fuller and wider investigation.

It would be premature therefore at present to generalise upon the nature of these occurrences from a genetic point of view, until such further examinations shall have been carried out, not only in this particular area, but in other localities where different modes of occurrence of cassiterite are now known. The conclusions thus to be drawn would unquestionably be of more value than any suggested by observations only applicable to a few cases.

In conclusion the writer wishes to acknowledge valuable assistance received, while visiting the various workings, from Messrs. Maggs & Munro, Mr. Tomlinson, foreman of the Government workings, and Mr. Stevens, manager of Groenfontein-Roodepoort mines. The writer is also indebted to Mr. U. P. Swinburne, Inspector of Mines, and Mr. T. G. Trevor, Deputy Inspector of Mines, for much useful information.

* See Geologist's Report of Progress, F.M.S., 1907, pp. 37–40.

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VIII.

SUMMARY OF A TRAVERSE IN THE NORTH-WESTERN ZOUTPANSBERG DISTRICT.

By E. T. MELLOR (*Geologist*).

VIII.—SUMMARY OF A TRAVERSE IN THE NORTH-WESTERN ZOUTPANSBERG DISTRICT.*

By E. T. Mellor (*Geologist*).

Route.—The route followed was from Pietersburg by the old Rhodesian road to Rhodes Drift, down the Limpopo by way of the Seta Mine to Middle Drift, and thence by Bulai Kop to the Messina Mine, and back via the M'Tamba copper workings and Louis Trichardt to Pietersburg. Deviations were made to the Blaauwberg and eastern end of the Zoutpansberg to the northern bank of the Limpopo, and to numerous localities where prospecting work was being carried on. From Pietersburg to the Limpopo and from the Messina Mine to Pietersburg travelling is comparatively easy, but in most other cases the only available routes are devious, thick bush and the absence of roads making progress extremely laborious and slow. The time occupied by the traverse was from 17th June to 29th July.

The following is a summary of the more important geological results :—

(1) *The Complex of older granites, gneisses, schists, and metamorphic rocks* occurring to the north and east of Pietersburg form the greater part of the surface of the country as far as and beyond the Limpopo, with occasional occurrences of sedimentary rocks.

(2) *The Zoutpansberg and Blaauwberg* are composed of rocks of the Waterberg System, entirely similar in general character to those already surveyed in other districts. The Lower Divisions of the System, whose relationships have been recently worked out by the Survey in the Middelburg District, are represented in the Zoutpansberg, and were met with in the neighbourhood of the copper workings at M'Tamba.

(3) *The Sandstones of the Limpopo Valley*, which occupy very considerable areas on both sides of the river, are identical with the Bushveld Sandstones of the Springbok Flats and of the Komatipoort Coal-field. The fossil reptile bones recently found in the Limpopo Valley occur in these sandstones, and their determination as of Stormberg Age confirms the geological position to which these sandstones in other parts of the Transvaal have been allocated by the Survey.

The same sandstones probably correspond to the Forest Sandstones of Rhodesian Geologists.

(4) *The Tuli Amygdaloids* which overlie the sandstones of the Limpopo Valley are probably identical in origin and geological position with the Bushveld Amygdaloid.

(5) *Coal-measures* occur in several localities north of the Zoutpansberg, mainly along the larger river valleys, such as those of the Sand and M'Tamba Rivers. These coal-measures are very similar in character to those further south in the Transvaal, but, where examined, they do not appear to be very extensively developed, and their total thickness probably does not exceed 150 feet. Thin coal seams occur in the lower portion of the measures, but no prospecting work of any importance has been done upon them. At Roet's claims on the Messina road, about four miles south of the M'Tamba River, where a shaft has been sunk, the coal is much mixed with shaly and stony bands. The comparatively poor development of the coal-measures and the character of the beds constituting them, in the examples met with, does not compare favourably with the better-known coal-bearing areas of the Transvaal, but the very small amount of prospecting work so far accomplished cannot be regarded as a satisfactory test. The results obtained are sufficiently encouraging to justify the hope that more extensive areas of coal-measures containing seams of more workable character may be found in the district.

Very interesting, from a geological point of view, was the discovery of an occurrence of the Glacial or Dwyka Conglomerate underlying the coal-measures in one locality on the north side of the Zoutpansberg, this being much further north than any occurrence previously known.

* For a fuller account of this traverse see "Report on a Reconnaissance of the N. W. Zoutpansberg District," by T. G. Trevor and E. T. Mellor, Pretoria, 1908.

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(6) *The diamond-bearing gravels of the "Seta" and "Bergdahl's"* were carefully examined. Apart from their economic aspect, they are of very great geological interest. Their main geological features have been dealt with in a special report already published. There appears to be no ground for doubting the diamondiferous character of these gravels; the quantity of material available for treatment, however, is likely to be overestimated. With regard to their bearing on the district, as a whole, they cannot be regarded as likely to exert very great influence on its development. Given sufficient water-supply, for which provision is being made in both cases, the deposits should be easily and quickly worked, but the quantity of material is not such as will maintain any considerable number of workers for any lengthy period.

The view has been put forward that the deposits at Bergdahl's represent a "pipe." There is, however, no foundation for such a statement, the alluvial character of the deposit being beyond question, a fact which is sufficiently evident from the nature of the materials submitted from time to time for examination to the Survey Laboratory, apart from an inspection of the deposits *in situ*.

It is, of course, possible that further deposits of the older gravels may be found. Remnants occur over several of the farms adjoining that on which the Seta Mine is situated, but prospecting up to the present has not resulted in locating any further deposits of any depth. Considering that very active prospecting work has been carried on during the past winter, that the older gravels are very easily recognisable where present, and that the Seta deposits themselves are of a very fragmentary character, it does not appear probable that any extensive deposits such as would be likely to give rise to mining activity in any considerable scale are likely to be found.

On the strength of the occurrence of diamonds in the Seta gravels, a good deal of prospecting has recently been done along the Limpopo Valley in the gravels and alluvium of the present river. In some cases this prospecting appears to have been carried on under capable men with a bona fide intention of testing a given property. In other instances, however, men entirely without previous experience on diamond-fields, and with scarcely a notion of what they are looking for, have been sent out without direction or supervision to prospect a property. The work done by these men usually consists in putting down a large number of haphazard holes. In many instances the information afforded by such holes could be obtained by a simple inspection of the surroundings or of the natural section given in the neighbouring river banks. In one instance over two hundred holes had been put down by a prospector, of which not more than half a dozen had been carried sufficiently far to afford information of any value. In some cases the older gravels, such as occur at the Seta, had not been seen by prospectors, and the very great difference between them and the later gravels was not recognised. It is probable that extensive tracts of older gravel have been swept away by later streams and deposited in the present bed of the Limpopo. In that case they could only be expected to have come to rest in the deepest parts of the river bed, below water-level, and to have become considerably intermixed with the later deposits. The difficulties attending their discovery and subsequent working are so great that they should be fully realised by those undertaking such enterprises.

(7) *Occurrences of Copper.*—By far the most important of the copper occurrences in the district traversed is that at the Messina Mine. The ore bodies here met with are of considerable size, and contain a large proportion of ore of high grade. For the most part this consists of copper-glance. It is said not to show any disposition to be replaced by copper pyrites in depth. The fact that the central portions of some of the larger masses consist of pyrites appear to indicate that that is the original form of the ore.

The small amount of gangue occurring with the Messina ore is a great point in its favour, enabling a large proportion of rich material to be sorted and bagged for export without much difficulty.

The Messina copper is sometimes stated to occur in "lenses," and since the country rock is a gneissoid granite, this conveys the impression that the ore bodies are of the lenticular and disconnected character frequently found in gneissic or schistose rocks.

The country rock of the Messina Mine, while showing a certain degree of foliation, is rarely, if ever, schistose, and is for the most part extremely massive in character. The fissures which traverse it appear to be persistent and continuous over long distances. The larger ore-bodies occurring in the wider portions of the fissures are connected by definite leaders. The lateral extent of this fissuring, as shown by the occurrence of extensive old native workings over several miles of country, justify the belief that the bodies will be found to persist also in depth.

The character of the Messina lodes and of the type of country prevailing in the locality give good ground for the hope that other payable mines will be found, either on its extension or in the immediate neighbourhood, and the character of the district is one which justifies considerable prospecting work being done upon it. It is a notable point that practically all the known copper occurrences of any note in the Messina district are on the sites of the old native workings. It appears improbable that these older workers, careful prospectors as they were, could have located all the important lodes.

Of the farms situated at some distance from the Messina on which copper has been found, somewhat promising indications have been met with on Oestenryk and Papenbril, although, as far as can be judged at present, the mineralization appears to have taken place somewhat diffusely along broad zones of fracturing rather than in well-defined fissures, as at the Messina, a feature which may be due to the less massive character of the country rock.

(8) *The occurrence of copper at M'Tamba* is deserving of special mention. It is interesting as an instance of a marked occurrence of copper not previously discovered or worked, and also for the beautiful specimens of native copper which have been obtained. It is further remarkable in so far as the copper occurs in strata belonging to the lower portion of the Waterberg System, whose relationships have only recently been worked in the Middelburg District, and which, although covering thousands of square miles in the Transvaal, has hitherto yielded little in the way of minerals of economic importance. There appears to be a want of definiteness and persistence in the veins in which the copper occurs at M'Tamba as far as these have yet been investigated, but the locality is one well deserving of adequate prospecting work being expended upon it.

IX.

ADDITIONS

TO

THE MUSEUM AND LIBRARY.

IX.—ADDITIONS TO THE MUSEUM AND LIBRARY.

1. LIST OF ADDITIONS TO MUSEUM COLLECTION.

DONOR.	NO. IN COLLECTION.	DESCRIPTION.	LOCALITY.
C. T. E. More	IV. 412	Hole stone	Brug Spruit.
— — Williams	IV. 413	Malachite and Apatite in Hematite	Tweefontein(1033),Potgiet'rsr'st
	IV. 414	Pitchstone	Moorddrift, Potgietersrust.
	IV. 415	Pyritic leader	Wolhuter G.M.
	IV. 416	Kimberlite	De Beers D.M.
	IV. 417	Matrix with Bornite	Krokodilkop.
D. Zeederberg	IV. 418	Chromite	Selukwi, Mashonaland.
U. P. S. Swinburne	IV. 419	Cassiterite in matrix	Zaaiplaats.
H. Kynaston	IV. 420	Siderite	Willows, Pretoria.
Do.	IV. 421	Malachite in Gossan	Do.
Do.	IV. 422	Bornite and Malachite in Quartz	Do.
Irrigation Department	IV. 423	Basalt	Stud Farm, Bethal.
	IV. 424	Matrix carrying free gold	Ruitjeslaagte, Pretoria.
E. T. Mellor	IV. 425	Piedmontite	Messina, Zoutpansberg.
W. G. Webster	IV. 426	Tourmaline rock	Verdoornsdraai, Waterberg.
A. Myers	IV. 427	Epidote with Antimonial Galena	Hertogenbosch (518),Waterberg.
E. F. Linder	IV. 428	Chromite	Zandfontein, Pretoria.
H. Kynaston	IV. 429	Galena	Edendale, Pretoria.
W. Pachonick	IV. 431	Quartzite with sulphide sublimate	Rustplaats, Lydenburg.
T. P. Trevor	IV. 432	Norite	Gubb's claims.
C. Gardthausen	IV. 433	Norite	Jachtlust, Zoutpansberg.
Do.	IV. 434	Hypersthenite	Do. do.
Do.	IV. 435	Olivine associated with Magnesite	Do. do.
Do.	IV. 436	Hypersthenite with chromite	Do. do.
J. Smuts	IV. 437	Smoky quartz	Fort Weeber.
U. P. S. Swinburne	IV. 438	Tin ore	Zaaiplaats, Waterberg.
	IV. 439	Tin ore	Do. do.
— — Beverley	IV. 443	Galena	Vergenoeg (3), Marico.
U. P. S. Swinburne	IV. 444	Chalcocite	
Do.	IV. 445	Cassiterite and Galena	Waterberg.
— — Barber	IV. 446	Grossularite	Oshoek, Lydenburg.

A series of rocks illustrating the sequence of intruded strata, from the Kimberley Mines .. De Beers Mining Co.

The collection of micro-sections was increased by the addition of ninety-five specimens, the whole of which were cut and prepared in the Laboratory of the Geological Survey.

2. ADDITIONS TO THE LIBRARY.

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England and Wales—

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,, 300. Economic Geology of the Amity Quadrangle.
,, 301. Bibliography and Index of North American Geology, Petrology, and Mineralogy, 1901–05 inclusive.
,, 302. The Areas of the United States, The States, and The Territories.
,, 303. Preliminary Account of Gold-field Bull-frog and other Mining Districts in Southern Nevada.
,, 304. Oil and Gas Fields of Greene County, Pennsylvania.
,, 305. The Analysis of Silicate and Carbonate Rocks.
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,, 307. Manual of Topographic Methods.
,, 308. A Geologic Reconnaissance in South-western Nevada and Eastern California.
,, 310. Results of Primary Triangulation and Primary Traverse.
,, 311. The Green Schists and Associated Granites and Porphyries of Rhode Island.
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,, 313. The Granites of Maine.
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„ 230. Ammanford (Solid).
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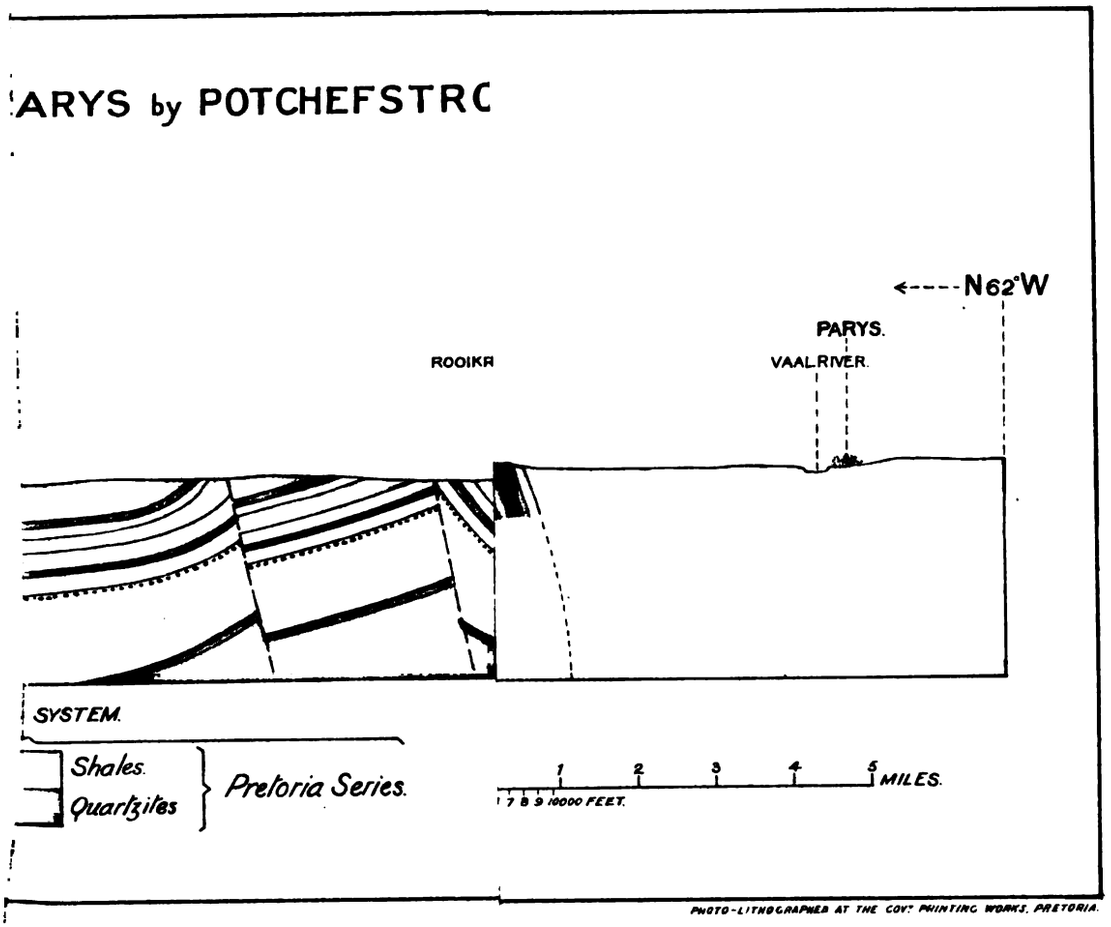
Plate VIII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PARYS.
ROOIKR
VAAL RIVER.
SYSTEM.
Shales.
Quartzites
Pretoria Series.
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1 7 8 9 10000 FEET.
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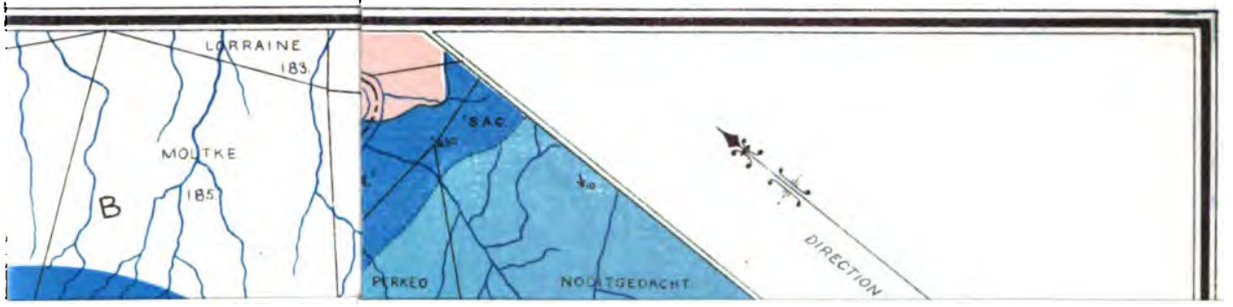
Plate IX.

TS, INCLUDING THE HAENERTSBURG GOLD FIELDS.



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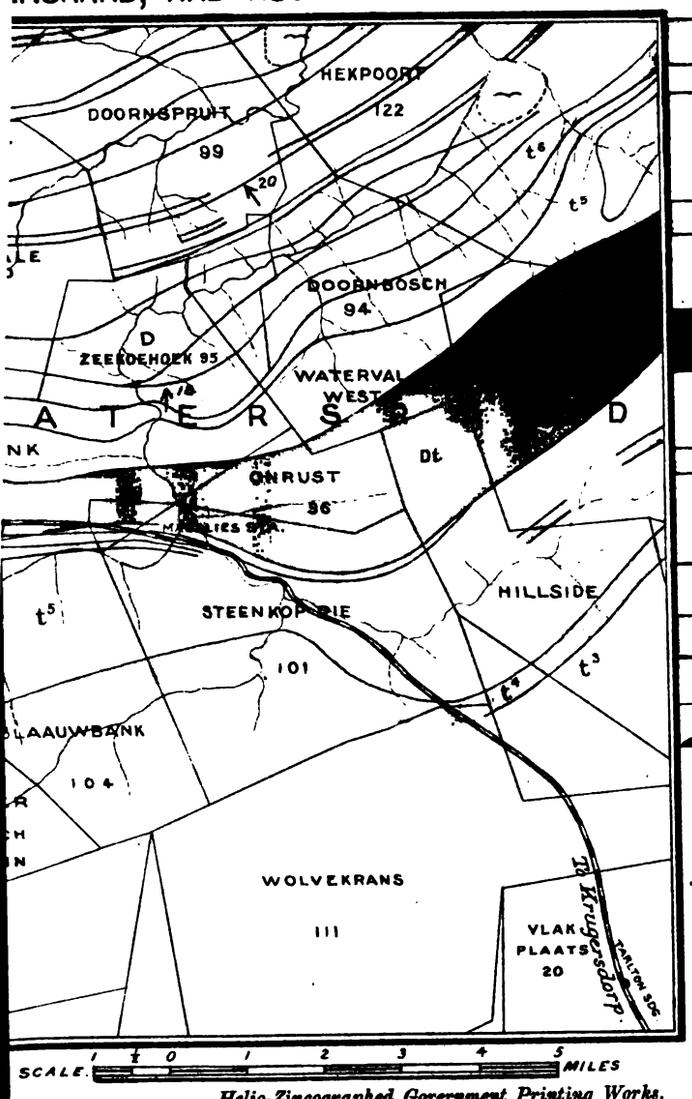

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- Alluvial deposits.
- t^7 Shales.
- t^6 Quartzites (Daspoort horizon.)
- t^5 Shales.
- Basic amygdaloidal lava. (Contemporaneous flow.)
- t^5 Shales.
- t^4 Quartzites, with magnetite bands. (Time-ball Hill horizon.)
- t^3 Shales.

Pretoria Series.

- D Intrusive diabase.
- S Syenite dykes
- 5 Direction of dip of strata with amount in degrees.
- Faults.

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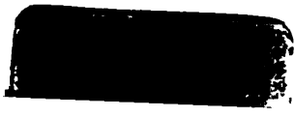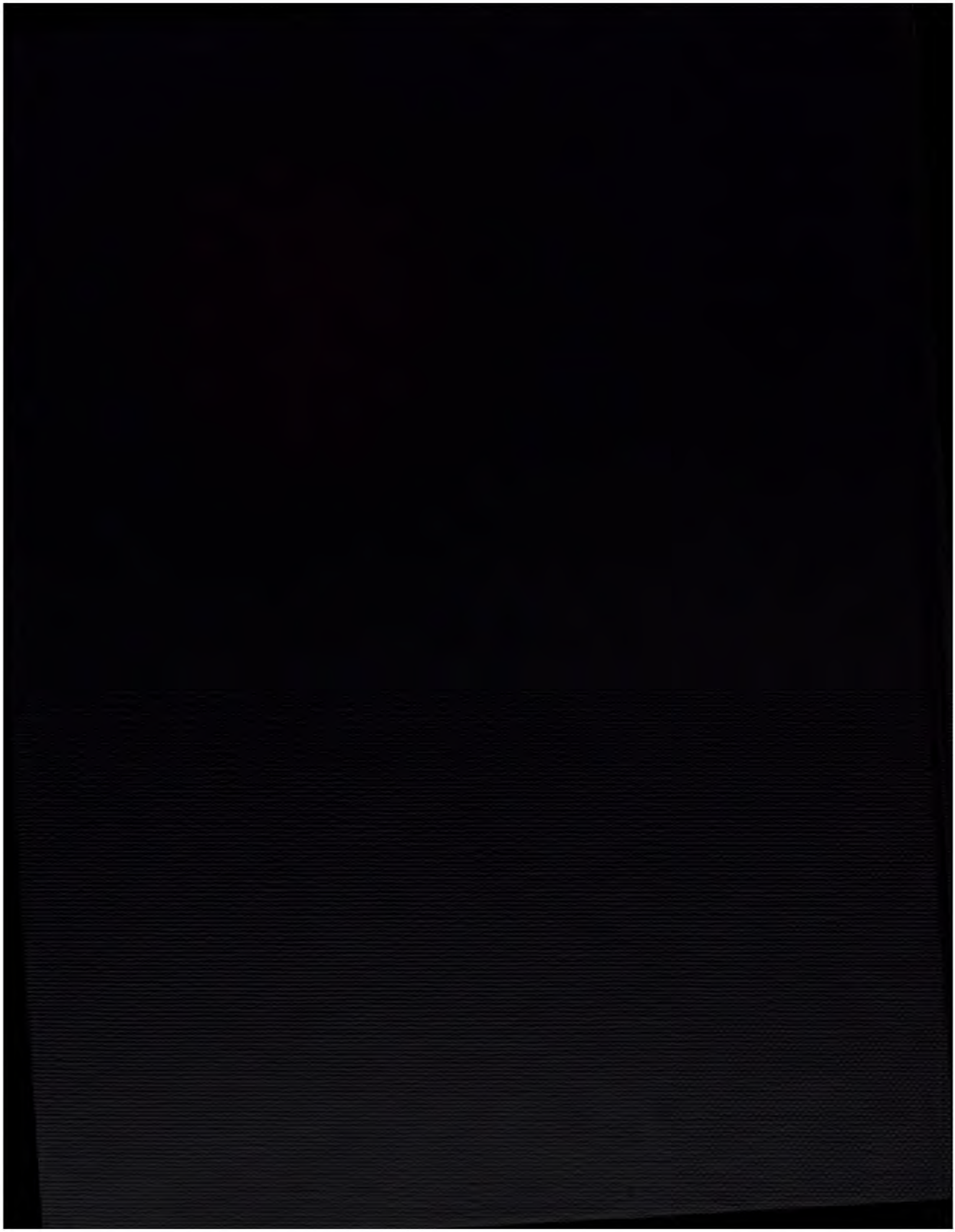
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